13. Media-dependent layer specification for interface to IEEE 802.3 passive optical network (PON) link

13.1 Overview

This clause specifies the service interface primitives, state machines, and packet format(s) that support accurate clock synchronization across 802.3ah links through the use of the Multi-Point Control Protocol (MPCP) and measurements specified in 802.3ah.

13.1.1 Description of the Multi-Point Control Protocol

802.3ah defines the Multi-Point Control Protocol (MPCP) to enable a MAC Client to participate in a point-to-multi-point optical network. MPCP allows a MAC Client to transmit and receive frames as if it was connected to a dedicated link. The timing process in MPCP relies on the 32-bit counters at both the Optical Line Terminal (OLT) and the Optical Network Unit (ONU). These counters provide a local time stamp that increases every tick, which is equal to 16 ns. When either the clock-master (OLT) or the clock-slave (ONU) transmits an MPCP Data Unit (MPCPDU), it maps its counter value into the timestamp field.

The 32-bit timestamp field conveys the content of the localTime register at the time of transmission of the MPCPDUs. It counts time in 16 bit time granularity. When the clock-slave receives MPCPDUs, it sets its counter according to the value in the timestamp field in the received MPCPDU. When the clock-master receives MPCPDUs, it uses the received timestamp value to calculate or verify a round trip time (RTT) between the OLT and the ONU. The RTT is equal to the difference between the timer value and the value in the timestamp field. This RTT can be used for the ranging process.

In the discovery processing, newly connected or off-line ONUs are provided access to the PON. The process is driven by the OLT, which periodically makes available Discovery Time Windows during which off-line ONU's are given the opportunity to make themselves known to the OLT. The first message of the round-trip (called 'discovery gate') is initiated within the 802.3ah MAC as a result of invoking the MA_CONTROL.request() primitive by the clock-master (the OLT, or the 'requester'). As defined by 802.3ah, upon receipt of the resulting broadcast GATE message, the clock-slave (a newly connected or off-line ONU, or the 'responder') waits for the period to begin and then transmits a REGISTER_REQ message to the requesting station. The following timestamps are captured during this two-message exchange:

— *t1* is when (in the requester's local time counter value) the GATE message is transmitted by the requester
— After receiving the GATE message, the responder sets its counter to *t1*
— *t2* is when (in the responder's local time counter value) the REGISTER_REQ message is transmitted by the responder after a wait period
— *t3* is when (in the requester's local time counter value) the REGISTER_REQ message is received by the requester

The RTT between the requester and responder is calculated by the requester as (*t3*-*t2*). Once an ONU is registered, verification of the RTT is conducted by the report and gate processing.

13.1.2 Clock synchronization in 802.3ah

The 802.3ah ONU PHY performs loop timing. It recovers the clock from the received signal from the 802.3ah OLT PHY and uses it to determine the timing of transmitter operations. Loop timing in the 802.3ah network locks the clock-slave of an ONU to the clock-master of the OLT. Transmission in the 802.3ah downstream link from the OLT to the ONUs is driven by time division multiplexing (TDM). In the upstream link from the ONUs to the OLT, time division multiple access (TDMA) is employed. Due to the frame queuing of TDMA, the downstream delay is different from that of the upstream. Towards the end of handling link asymmetry, the accurate clock synchronization across 802.3ah is operated as follows. It is assumed that the clock-master (the OLT, or the 'requester') has an accurate network synchronized time, obtained through IEEE 1588 or other means. The clock-master informs the clock-slave (the ONU, or the 'responder') what the accurate clock synchronization will be when the counter of the clock-slave reaches a certain value. The information transfer can be accomplished using the MPCP <<See Editor's note>>, and does not need to be in real time. When the counter at the clock-slave reaches the selected value, the ONU can update its local clock with high accuracy.

The following reference process will result in the clock-slave of ONU being synchronized to the clock-master of OLT:

1) The clock-master selects a timestamp value X that will be used as the timing reference. This timestamp must occur far enough in the future so that the messages are processed in time.

2) The clock-master calculates the $\mathbf{ToD}_{X,i}$ value, which is the time-of-day when the first bit of a downstream MPCP message that would carry a timestamp of X would have arrived at a clock-slave, based on the predicted $\mathbf{ToD}_{X,0}$. $\mathbf{ToD}_{X,0}$ is the exact time-of-day at which the first bit of a downstream MPCP message that would carry the timestamp *X* would have departed from the clock-master. This calculation is given by:

$$ToD_{X,i} = ToD_{X,0} + RTT_i \frac{n_{1490}}{n_{1310} + n_{1490}}$$

RTT $_i$ is the round trip time measured by the clock-master for clock-slave *i*, *i.e.*, ONU*i*. $\boldsymbol{n_{1310}}$ is the index of refraction for 1310nm wavelength light in the ODN. $\boldsymbol{n_{1490}}$ is the index of refraction for 1490nm wavelength light in the ODN.

3) The clock-master sends this value pair (*X*: $\mathbf{ToD}_{X,i}$) to clock-slave *i* via the downstream TIMESYNC message.

4) After the clock-slave receives the downstream TIMESYNC message, it sets its counter according to the value in the timestamp field in the received TIMESYNC message. When the counter of the clock-slave reaches X, the clock-slave sets its clock to the value $\mathbf{ToD}_{X,i}$ plus any internal delays.

Note that the above time-of-day values are all references to the optical interface, which is the optical connector or splice that is the boundary between either the clock-master (the OLT) or the clock-slave (the ONU) and the ODN. ***RTT*** $_i$ should not include any internal clock-master delays. It is measured relative to the optical departure and arrival times

<<Editor's note: The MPCP messages related to clock synchronization in EPON are not defined in 802.3 standard yet, perhaps this could be done in the time sync study group>>

13.2 Message attributes

13.2.1 Message class

13.2.1.1 Discovery message class

The discovery message class contains the following message types:

a) GATE
b) REGISTER_REQ
c) REGISTER
d) REGISTER_ACK

13.2.1.2 Report message class

The report message class consists of the following message type:
a) REPORT

13.2.1.3 Gate message class

The gate message class consists of the following message type:
a) GATE

13.2.1.4 Time synchronization message class

The time synchronization message class consists of the following message type:
a) TIMESYNC

13.2.2 Event message timestamp point

Since event messages are timestamped within the 802.3ah MAC/PHY, the timestamp points should be and are defined in 802.3ah.

13.3 Message formats

<<Editor's note: Message formats of clock synchronization in EPON are not defined in 802.3 standard yet, perhaps this could be done in the time sync study group- the messages are generated and consumed within the 802.3ah MAC.>>

13.4 Service interface primitives

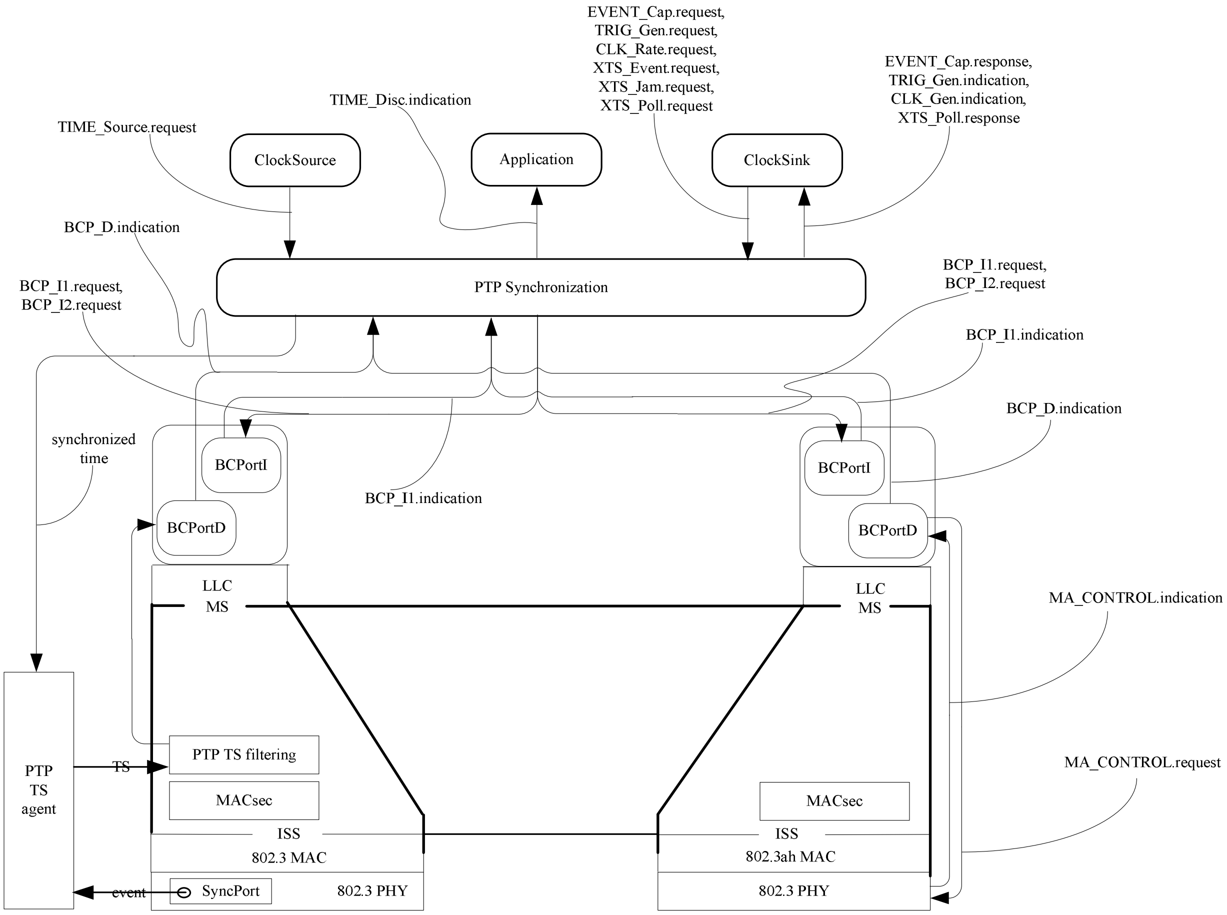

Figure 13-1—802.3ah interface model

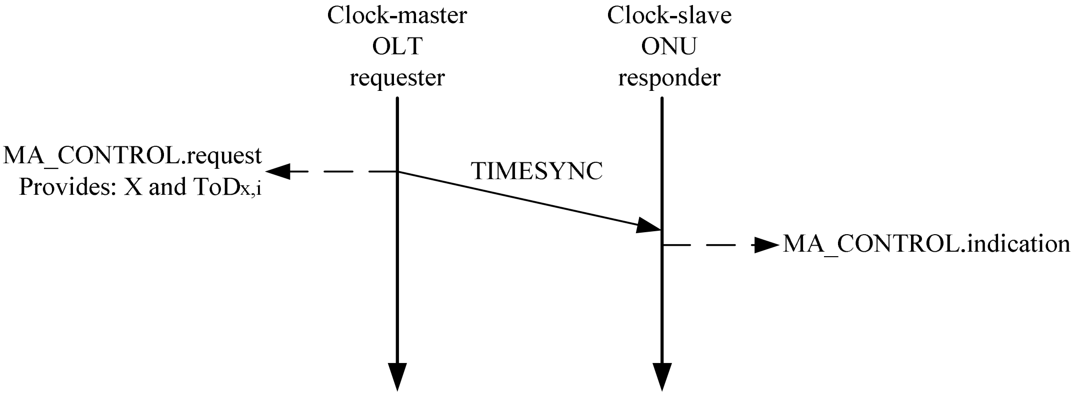

Figure 13-2—802.3ah time-synchronization interfaces

The properties of these service interfaces are summarized below:

MA_CONTROL.request

Generated periodically by the clock-master entity.

Triggers transmission of a TIMESYNC message.

NOTE: Value pair of (X: $\mathbf{ToD}_{X,i}$) is sent to the clock-slave.

MA_CONTROL.indication

Generated after receiving a TIMESYNC message.

Value pair of (X: $\mathbf{ToD}_{X,i}$) is captured by the clock-slave.

13.5 Service interface definitions

13.5.1 MA_CONTROL.request

13.5.1.1 Function

The service interface triggers the sending of a TIMESYNC message from the clock-master requester to the clock-slave responder. A value pair of (X: $\mathbf{ToD}_{X\,i}$) is sent to the clock-slave via the TIMESYNC message.

13.5.1.2 Semantics of the service primitive

The semantics of the primitives are as follows:

```
MA_CONTROL.request {
        X           //Used to identify a selected timestamp value
        $ToD_{X,i}$   //Used to identify the time-of-day value when the first bit of a downstream MPCP message that
                    //would carry a timestamp of X would have arrived at a clock-slave
}
```

13.5.1.3 When generated

Generated every SYNC_INTERVAL seconds in the MASTER state, as the first phase of a timesync information transfer.

13.5.1.4 Effect of receipt

Upon receipt, a TIMESYNC message is enqueued for transmission.

13.5.2 MA_CONTROL.indication

13.5.2.1 Function

The receipt of a TIMESYNC message by the responder provides a clock synchronization value pair (X: $\mathbf{ToD}_{X\,i}$) to the clock-slave.

13.5.2.2 Semantics of the service primitive

The semantics of the primitives are as follows:

```
MA_CONTROL.indication {
        X           //Used to identify a selected timestamp value
        $ToD_{X,i}$   //Used to identify the time-of-day value when the first bit of a downstream MPCP message that
                    //would carry a timestamp of X would have arrived at a clock-slave
}
```

13.5.2.3 When generated

Generated by the receipt of a TIMESYNC message during the phase of a time-sync transfer. A value pair of (X: $\mathbf{ToD}_{X,\,i}$) is saved to the clock-slave.

13.5.2.4 Effect of receipt

Upon receipt, a value pair of (X: $\mathbf{ToD}_{X,\,i}$) is captured.

13.6 State machines

13.6.1 Requester state machine

13.6.1.1 Function

This state machine generates and consumes 802.3ah-specific primitives used to provide accurate clock synchronization across 802.3ah links. Every (syncInterval) seconds, this state machine initiates individual clock synchronization.

13.6.1.2 State machine variables

13.6.1.2.1 syncIntervalTimer

A variable that represents the time since the last indication of the clock synchronization.

13.6.1.2.2 syncInterval

The value that represents the time interval to initiate the clock synchronization.

13.6.1.2.3 X

The value of timestamp that is selected as the timing reference.

13.6.1.2.4 $ToD_{x,i}$

The time-of-day when the first bit of a downstream MPCP message that would carry a timestamp of X would have arrived at the clock-slave.

13.6.1.2.5 $ToD_{x,0}$

The time-of-day when the first bit of a downstream MPCP message that would carry a timestamp of X would have departed at the clock-master.

13.6.1.2.6 n1490

The index of refraction for 1490nm wavelength light.

13.6.1.2.7 n1310

The index of refraction for 1310nm wavelength light.

13.6.1.2.8 RTTi

The RTT between the clock-master and the clock-slave *i*.

13.6.1.3 State machine functions

13.6.1.3.1 currentTime

This function gets the current time of the clock-master.

13.6.1.3.2 getRTTi

This function gets the RTT between the clock-master and the clock-slave *i*.

13.6.1.4 State transition diagram

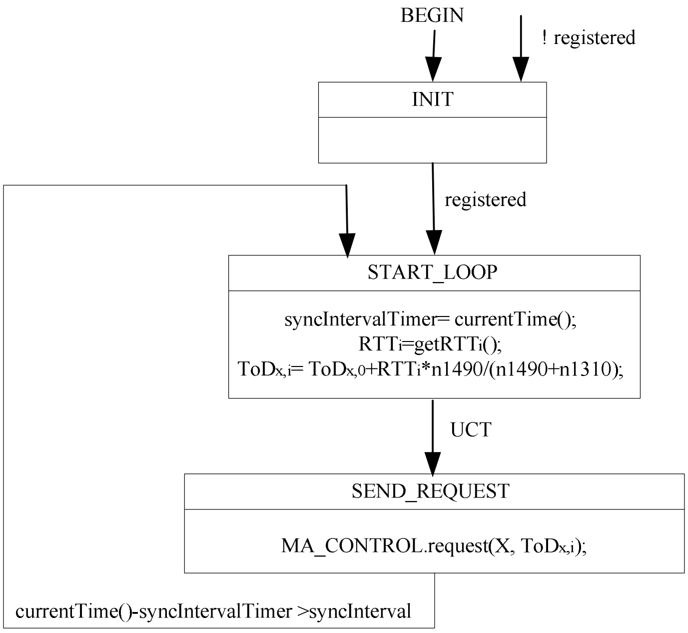

Figure 13-3—State machine for 802.3ah requester

13.6.1.5 Operation

13.6.2 Responder state machine

13.6.2.1 Function

This state machine responds to 802.11-specific primitives used to measure the time offset between the link partner (the clock slave) and itself (the clock master).

13.6.2.2 State machine variables

13.6.2.3 State machine functions

13.6.2.4 State transition diagram

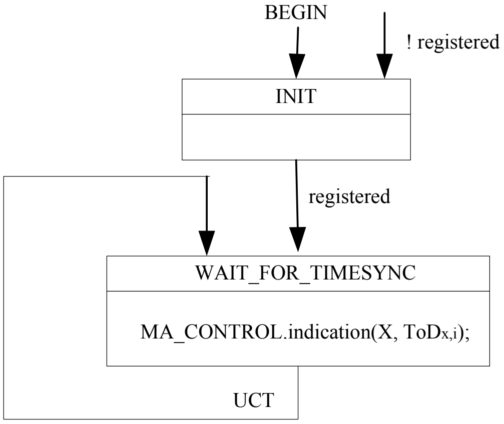

Figure 13-4—State machine for 802.3ah responder

13.6.2.5 Operation