144.3.1.1 Ranging Measurement and Time Synchronization

Both the OLT and the ONU have 32 bit counters (*LocalTime*) that increment by one every EQT. In the OLT, the *LocalTime* counter is synchronized with the OLT 25GMII transmit clock and increments synchronously with the *IN_CLK* (see 143.3.3.3). In the ONU, the *LocalTime* counter is synchronized with the 25GMII receive clock and increments synchronously with the *OUT_CLK* (see 143.3.4.3). In the ONUs supporting multiple downstream (receive) channels, the *LocalTime* is synchronized with the 25GMII receive clock of an active (enabled) channel with the lowest index.

The *LocalTime* counters supply the timestamp value for MPCPDUs transmitted by either device. The time reference point for the timestamp value is the transmission time of the Envelope Start Header (ESH) of the envelope that includes the MPCPDU (see 143.3.2). In situations where multiple MPCPDUs are transmitted within a single envelope, all these MPCPDUs shall have the same timestamp value, referencing the transmission time of ESH.

Note that the actual arrival times of MPCPDUs to the MAC Control sublayer do not affect the timing synchronization mechanism. MPCPDUs may get delayed in the transmitting MAC if, for example, the MAC is paused to allow for the MCRS rate adjustment or FEC parity insertion between the ESH and the MPCPDU.

The ONU ranging (i.e., round-trip propagation time) is measured during the ONU initial discovery and registration. The measured range value also includes the nominal delays of 32 EQT through the ONU MCRS receive data path and 32 EQT through the OLT MCRS receive data path (see 143.2.6.).

The method of ranging measurement is illustrated in Figure 144—x. It consists of the following steps:

1. The OLT Discovery Process transmits DISCOVERY MPCPDU with timestamp value equal to the *LocalTime* counter at the time when MCRS_CTRL.request primitive is generated by Envelope Activation Process. This is also the time when the ESH is written into the ENV_TX FIFO (see 143.3.1.2.1). Accordingly, the EPAM field of the ESH header matches the six least-significant bits of the *LocalTime* (*LocalTime*<5:0>).

2. When an unregistered ONU receives the DISCOVERY MPCPDUs, it sets its *LocalTime* counter according to the value in the *Timestamp* field in the received MPCPDU. From this moment, the *LocalTime* counter continues to increment synchronously with the 25GMII receive clock.

3. After the ONU's *LocalTime* counter reached the value of *GrantStartTime* and an additional random delay, the ONU Registration Process transmits REGISTER_REQ MPCPDU with timestamp value equal to the *LocalTime* counter at the time when MCRS_CTRL.request primitive is generated by Envelope Activation Process. This is also the time when the ESH is written into the ENV_TX FIFO (see 143.3.1.2.1). Accordingly, the EPAM field of the ESH header matches the six least-significant bits of the *LocalTime* (*LocalTime*<5:0>).

4. When the OLT receives MPCPDUs, it uses the received timestamp value to calculate the round trip time between the OLT and the ONU. The Round Trip Time (RTT) is equal to the difference between the OLT's *LocalTime* counter at the movement when the ESH is read from the MCRS ENV_RX buffer and the *Timestamp* field value in the REGISTER_REQ MPCPDU.

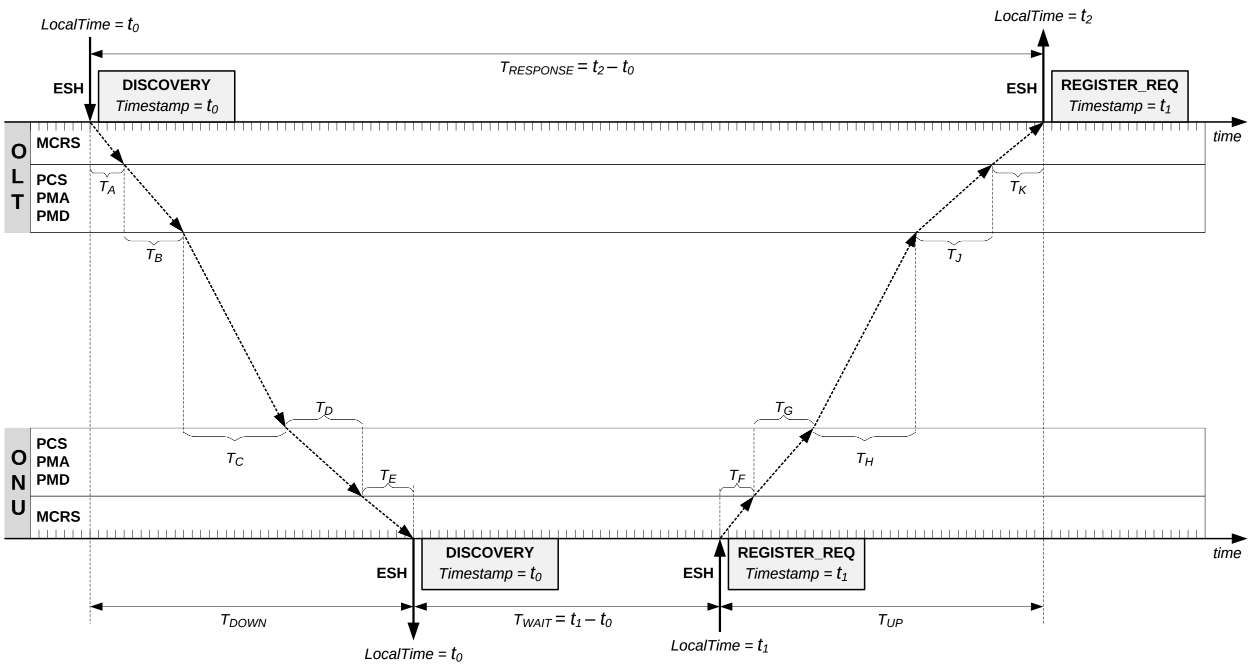

Figure 144—x: Ranging measurement

In the downstream direction, the combined delay T_{DOWN} includes the following delay components:

- T_A – delay through the transmit data path of the OLT MCRS sublayer.
- T_B – delay through the transmit data path of the OLT PCS, PMA, and PMD sublayers. This delay also includes FEC encoding delay.
- T_C – downstream optical signal propagation delay in fiber. In EPON systems supporting multiple downstream channels, this delay may be different on different channels.
- T_D – delay through the receive data path of the ONU PCS, PMA, and PMD sublayers. This delay also includes FEC decoding (correction) delay.
- T_E – delay through the receive data path of the ONU MCRS sublayer. During initial ranging, this delay is equal to 32 EQT (see 143.2.6). After the initial ranging, the delay T_E becomes inversely-correlated with the sum of delays T_B, T_C, T_D, and T_E, such that T_{DOWN} remains nearly-constant with only ± 1 EQT of variability.

In the upstream direction, the combined delay T_{UP} includes the following delay components:

- T_F – Delay through the transmit data path of the ONU MCRS sublayer.
- T_G – Delay through the transmit data path of the ONU PCS, PMA, and PMD sublayers. This delay also includes FEC encoding delay.
- T_H – Upstream optical signal propagation delay in fiber. In EPON systems supporting multiple upstream channels, this delay may be different on different channels.
- T_J – Delay through the receive data path of the OLT PCS, PMA, and PMD sublayers. This delay also includes FEC decoding (correction) delay.

— T_K – Delay through the receive data path of the OLT MCRS sublayer. During initial ranging, this delay is equal to 32 EQT (see 143.2.6). After the initial ranging, the delay T_K becomes inversely-correlated with the sum of delays T_F, T_G, T_H, and T_J, such that T_{UP} remains nearly-constant with only ± 1 EQT of variability.

As was stated above, the RTT value is equal to the difference between t_2 (the OLT's *LocalTime* counter at the movement when the ESH is received) and t_1 (the *Timestamp* field value in the *REGISTER_REQ* MPCPDU). Below is the derivation of this RTT value:

From the illustration in Figure 144-x, the total response time $T_{RESPONSE}$ (an interval of time from sending ESH with the *DISCOVERY* MPCPDU to the ONU and receiving ESH with the *REGISTER_REQ* MPCPDU from the ONU) is equal: $T_{RESPONSE} = t_2 - t_0$

On the other hand, $T_{RESPONSE} = T_{DOWN} + T_{WAIT} + T_{UP}$, where $T_{WAIT} = t_1 - t_0$

Thus, $t_2 - t_0 = T_{DOWN} + t_1 - t_0 + T_{UP}$.

$RTT = T_{DOWN} + T_{UP} = t_2 - t_1$.

Once the RTT is measured, the GATE generation Process for the new PLID is instantiated. That process is responsible for generating the GATE MPCPDUs to the registered ONU (PLID). All MPCPDUs send by the OLT on unicast PLID have the Timestamp value pre-compensated by the RTT associated with this PLID:

$$Timestamp[PLID] = LocalTime + RTT[PLID]$$

The effect of such timestamp pre-compensation is that the first ESH in any burst from an ONU will arrive to the OLT MCRS ENV_RX buffer approximately 32 EQT before their *GrantStartTime* values and this ESH will be read from ENV_RX buffer into the associated MAC instance at the time when the OLT's *LocalTime* counter value is equal to *GrantStartTime* (see Figure 144—y).

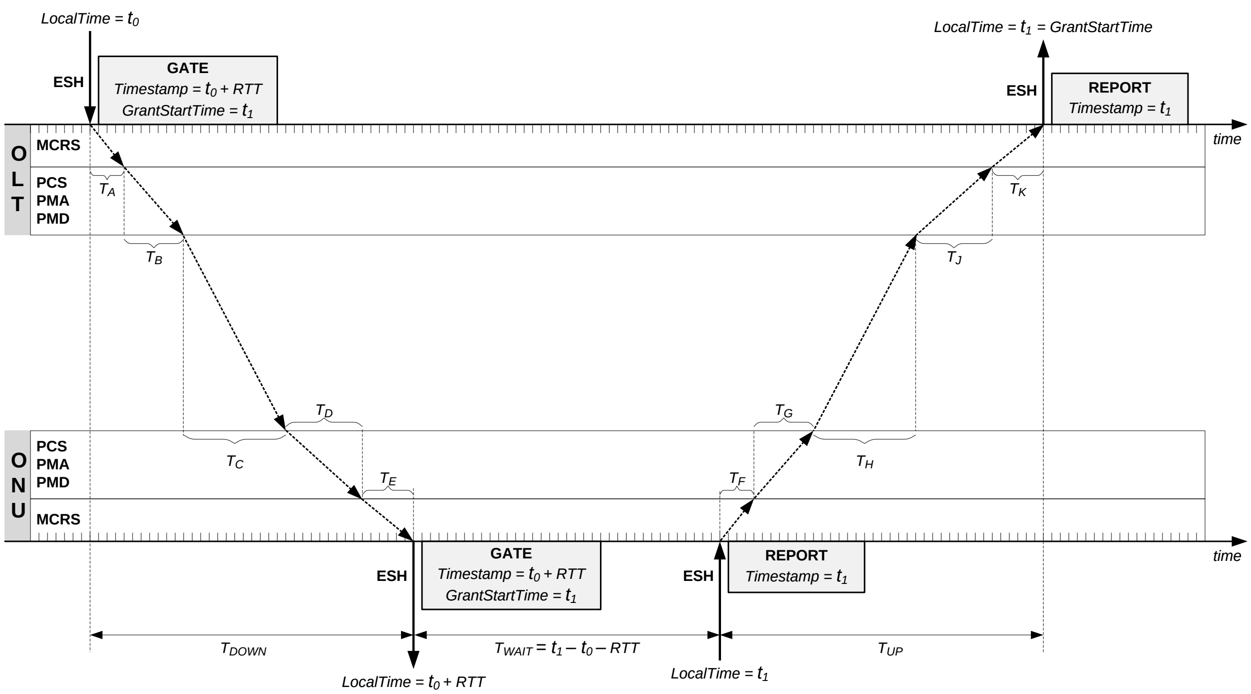

Figure 144—y: Illustration of *GrantStartTime* alignment

Another effect of the timestamp pre-compensation is that the *Timestamp* field value in a received MPCPDU is expected to match the *LocalTime* value at the time the MPCPDU is received. (As stated above, the timestamp reference point is the time the ESH is read from the ENV_RX buffer).

A condition of timestamp drift error occurs if the OLT's and ONU's *LocalTime* counters lose their synchronization or mutual alignment. This condition can be independently detected by the OLT or an ONU. This condition is detected when an absolute difference between the *Timestamp* value received in an MPCPDU and the *LocalTime* counter exceeds the timestamp drift threshold limit DRIFT_THOLD (see 144.2.1.4). The timestamp drift error causes an immediate ONU deregistration.

After the ONU receives the REGISTER MPCPDU with its assigned PLID and MLID, it stops processing any MPCPDUs received in envelopes with DISC_PLID. At this time, the ONU is ready to accept its first GATE received on the newly-assigned unicast PLID. The timestamp in this GATE MPCPDU is pre-compensated with ONU's RTT, and therefore, the ONU is expected to measure a large difference between the received *Timestamp* value and its *LocalTime* counter. This large difference detected immediately after the registration is expected and the ONU shall not recognize it as a timestamp drift error.