3-Layer EPON Protocol

Contributors:

Onn Haran (onn.haran@passave.com)

Ariel Maislos (ariel.maislos@passave.com)

JC Kuo (jc.kuo@alloptic.com)

Glen Kramer (glen.kramer@alloptic.com)

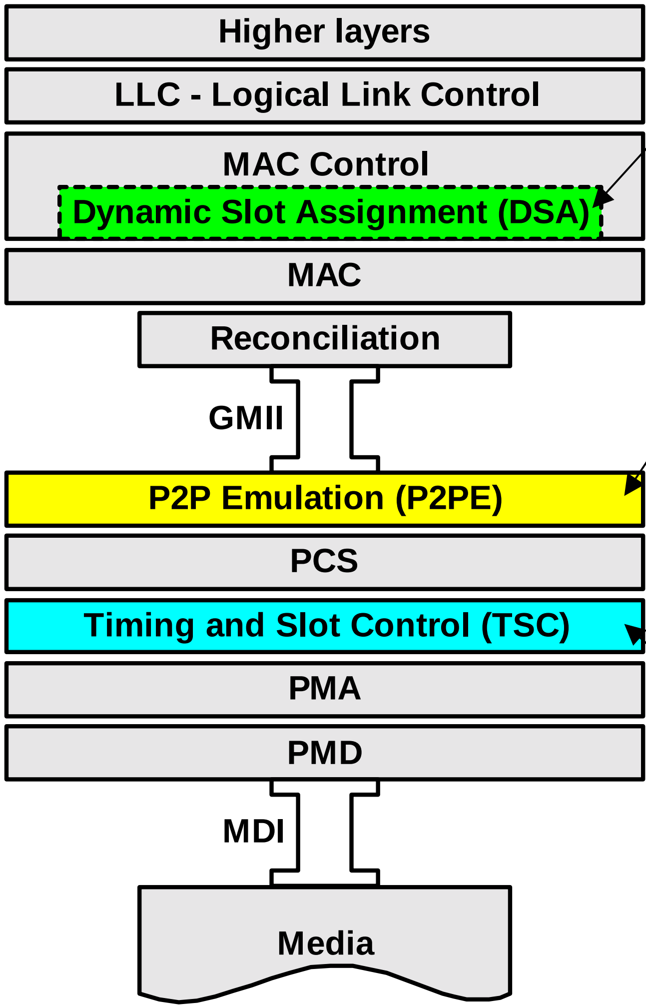
Protocol Ideology

- ONUs use time-sharing access to the media.
- Minimum or no changes to MAC.
- MAC and MAC control layers should not have timing constraints stricter than in current definition.
- PHY can reliably synchronize on incoming bit stream; Timing should be confined to PHY.
- PHY must be slot-aware to turn laser ON/OFF at right times.
- EPON is an efficient transport system - “smart pipe”. Higher layers should define algorithms to support QOS, prioritization, TDMA/SBA/DBA (analogy - switched Ethernet).
- Use OAM communication channel to carry all EPON specific messages.

Definitions

- Time Quanta (TQ) – A time unit for measuring time in EPON.
- Slot – interval of time when an ONU is allowed to transmit. A slot should be assigned (granted) to ONUs before the ONU can transmit its data.
  Slots have variable size (measured in TQ)
- Schedule – a snapshot of slot assignments to all ONUs
- Cycle – an interval of time covered by one schedule.
- Grant – a message from OLT assigning a slot to an ONU
- Request – a message from ONU reporting a change in traffic conditions (i.e., load, queue state, etc.) at ONU

Layer diagram



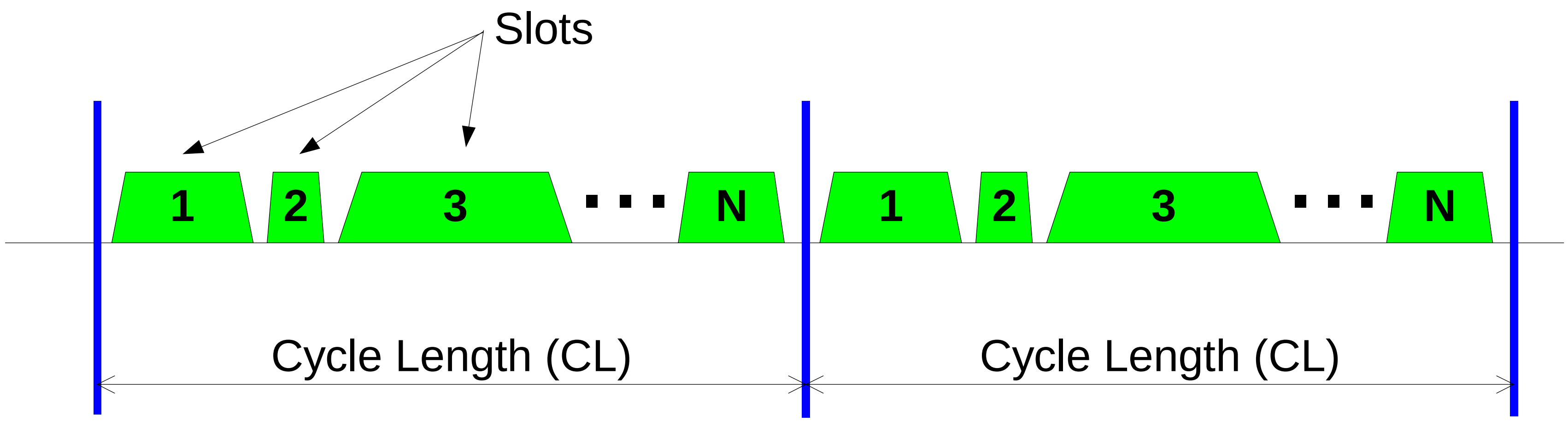
- **DSA defines messages and operations used to assign a slot to an ONU, revoke slot from ONU, and change slot size.**

- **P2PE is used to simulate independent virtual P2P links between OLT and each ONU. This layer ensures EPON's compatibility with flow control, link aggregation, bridging, etc (described in a separate presentation).**

- **TSC is time-aware and maintains cycle synchronization. It is responsible for turning laser ON and OFF at proper times.**

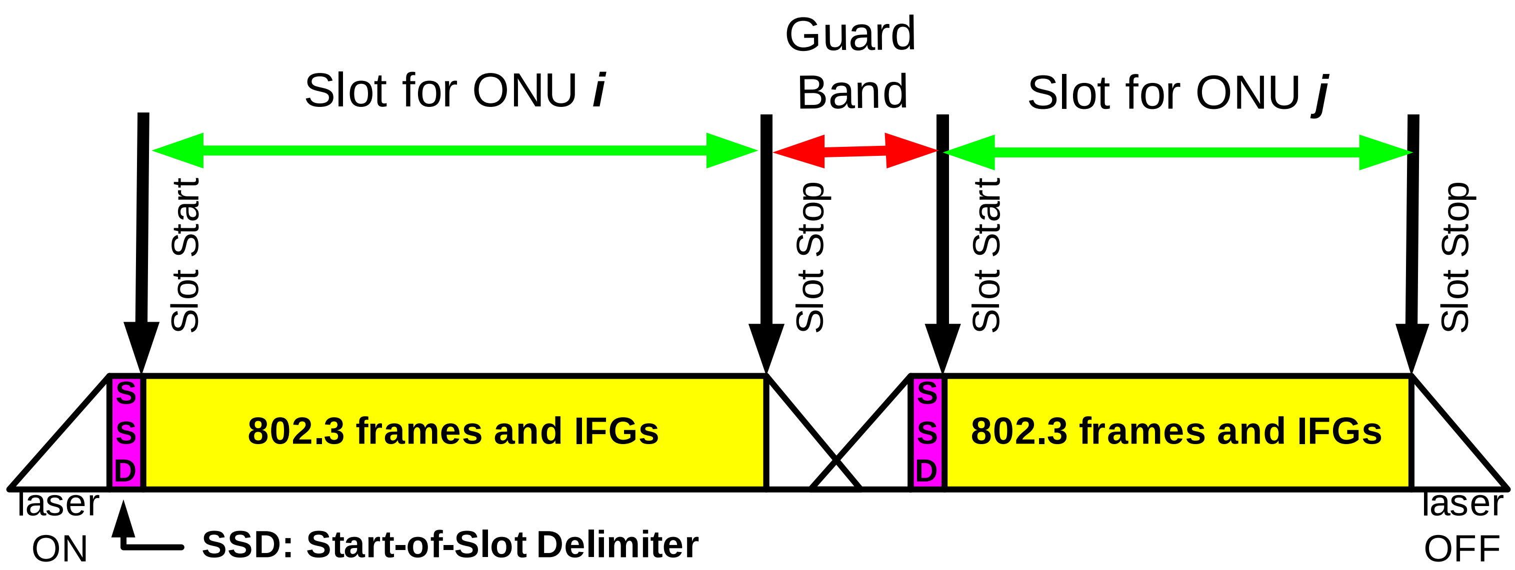
Timing & Slot Control (TSC) Layer

Slotted operation



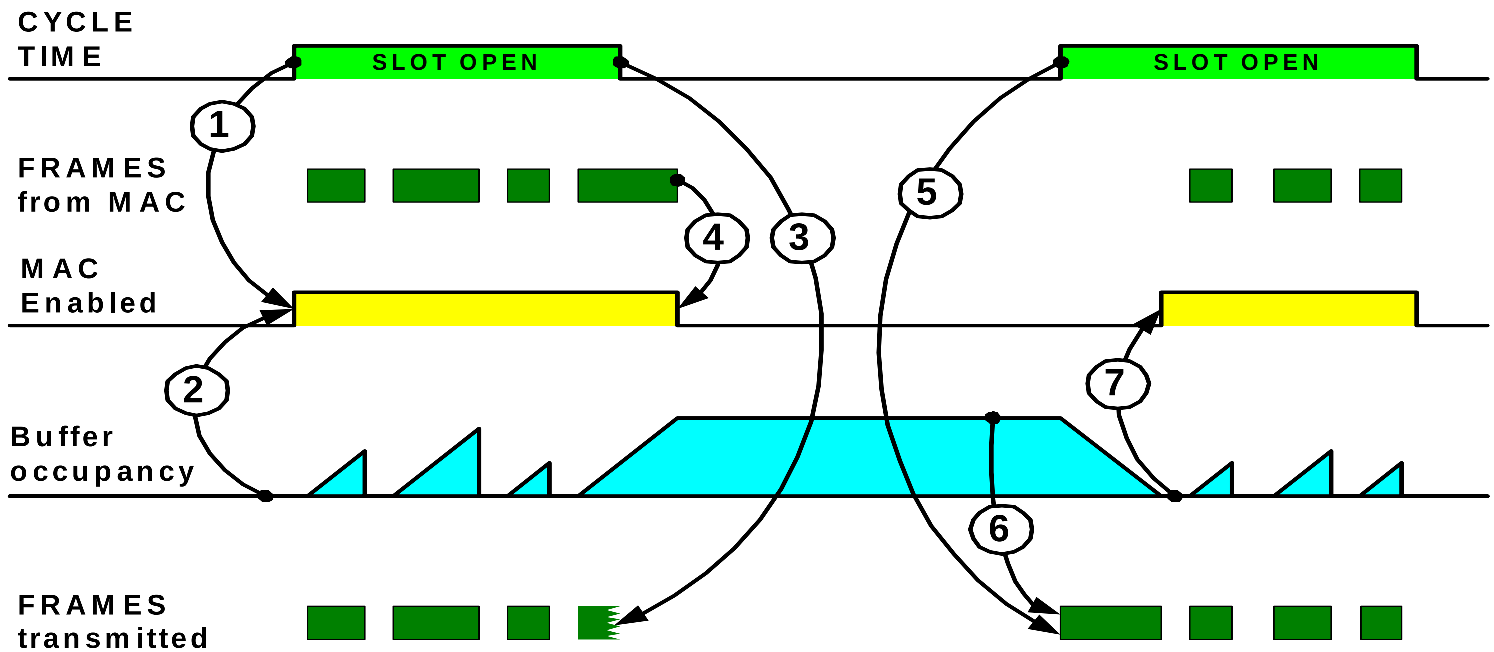
- Cycle length is fixed
- Slot length is expressed in **Time Quanta (TQ)**
- TQ is **tbd** bit times long (ex. 256 ns = 32 octets)
- Each ONU can have several slots assigned in a cycle
- If continuous slots assigned to a device, TSC does not shut down laser between slots.

Slot Structure



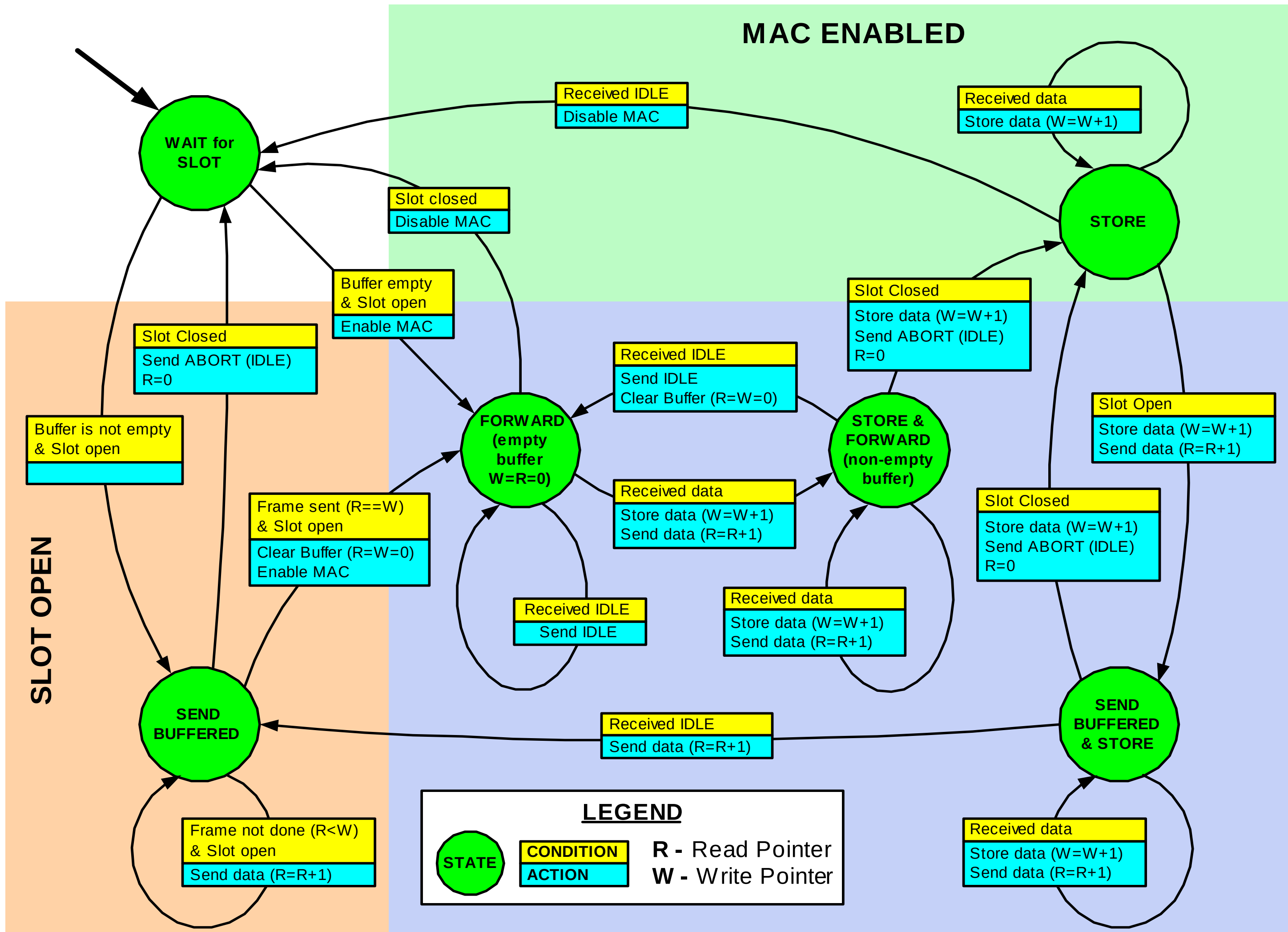
- Slot is defined by **Start Slot** and **Stop Slot** clocks
- Slots are assigned and revoked using **Grant** messages (defined in higher layer)
- No frame fragmentation within a slot

TSC timing diagram



- **TSC can buffer 1 frame**
- **When slot opens (1), if TSC buffer is empty (2), enable MAC**
- **When slot ends (3), abort PHY transmission**
- **When frame ends (4) after slot ended (3), disable MAC**
- **When slot opens (5), if buffer is not empty (6), transmit from buffer**
- **When buffer empties (7), enable MAC**

TSC State Transition Diagram

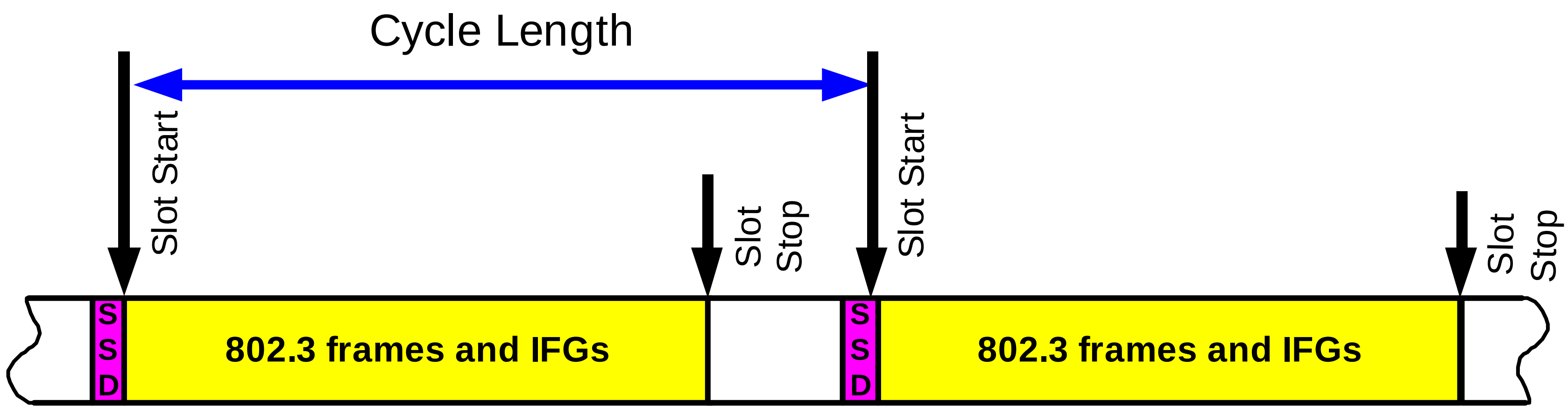


MAC augmentation

Function TransmitLinkMgmt (clause 4.2.8)

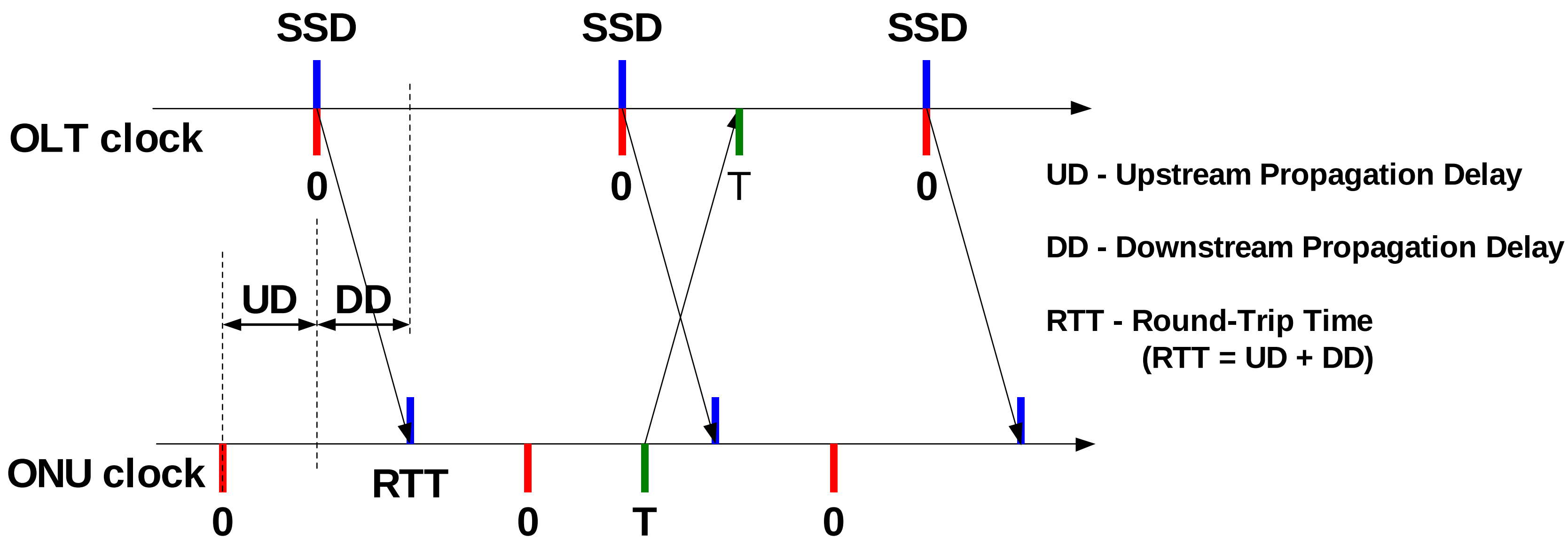
```
function TransmitLinkMgmt:TransmitStatus;
begin
        attempts :=0;
        transmitSucceeding :=false;
        lateCollisionCount :=0;
        deferred :=false;{Initialize}
        excessDefer :=false;
        while (attempts <attemptLimit) and (not transmitSucceeding) and (not extend or lateCollisionCount =0)do
                {No retransmission after late collision if operating at 1000 Mb/s}
        begin {Loop}
                if bursting then {This is a burst continuation}
                        frameWaiting := true {Start transmission without checking deference}
                else {Non bursting case,or first frame of a burst}
                        begin
                                if attempts > 0 then BackOff;
                                frameWaiting := true;
                                while deferring do {Defer to passing frame,if any}
                                        if halfDuplex then deferred := true;
                                burstStart :=true;
                                if burstMode then bursting :=true
                                while fullDuplex and not slotOpen do
                                        nothing;            {check slot condition}
                        end ;
                        lateCollisionError := false;
                        StartTransmit;
                        frameWaiting := false;
                        if halfDuplex then
                                begin
                                        while transmitting do WatchForCollision;
                                        if lateCollisionError then lateCollisionCount := lateCollisionCount +1;
                                        attempts := attempts +1
                                end {Half duplex mode}
                                else while transmitting do nothing {Full duplex mode}
                end ;{Loop}
                LayerMgmtTransmitCounters;{Update transmit and transmit error counters in 5.2.4.2}
                if transmitSucceeding then
                begin
                        if burstMode then burstStart := false;{Can 't be the first frame anymore}
                        TransmitLinkMgmt :=transmitOK
                end
                else if (extend and lateCollisionCount  > 0) then TransmitLinkMgmt := lateCollisionErrorStatus;
                else TransmitLinkMgmt :=excessiveCollisionError
        end ; {TransmitLinkMgmt}
```

Downstream transmission



- OLT assigned one slot which determines the cycle length.
- OLT transmits Start-of-Slot Delimiter (SSD) when its cycle clock equals 0.

ONU synchronization/ranging



- **Goal**: **If ONU sends a bit at time T (ONU clock), OLT must receive it at time T (OLT clock)**
- **How to achieve**: **ONU clock must be ahead of OLT clock by UD**
- **Procedure**: **If OLT sends a bit at time 0, ONU must receive it at time DD + UD = RTT.** ***RTT value must be known/conveyed to ONU***

ONU initialization

- 2 Steps:
  - Registration
    - Introduction (ONU MAC address, other parameters TBD)
    - Contention-based
  - Ranging
    - OLT measures RTT and sends it to ONU
    - One ONU at a time (no contention)
    - Periodic drift compensation

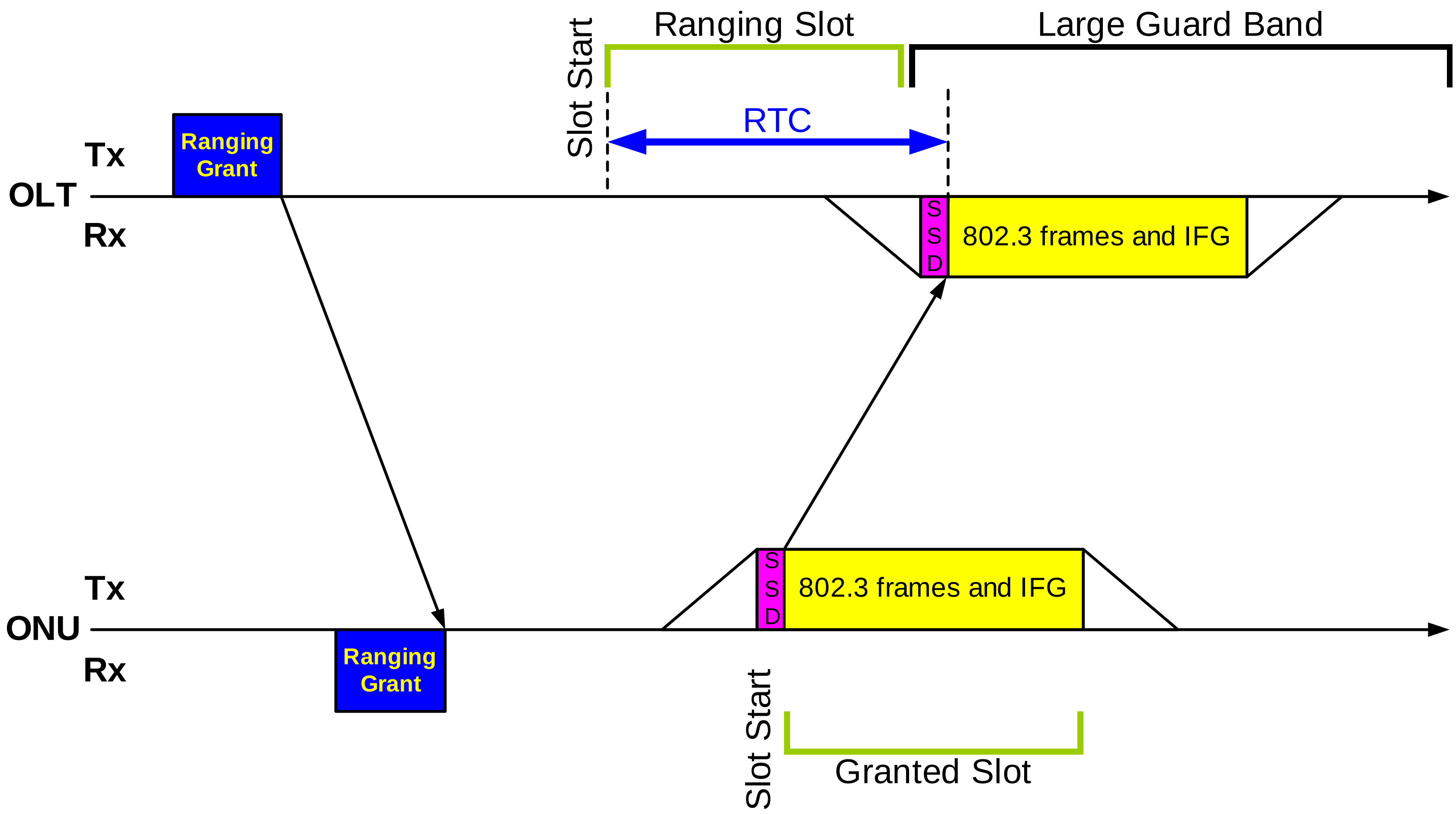
ONU registration

- OLT allocates registration slot and broadcasts Registration Grant.
- Each un-initialized ONU responds with an Introduction packet (format TBD).
- If Introduction Packet collision detected/inferred,
  - Skip random number of Registration Grants (exponential back-off)
  - On next (after back-off) Registration Grant send Introduction packet again

ONU ranging

- After a successful registration
  - OLT assigns a slot to the ONU (Ranging Grant)
  - OLT keeps large guard band since RTT is unknown
- ONU starts transmission
  - sends SSD and user data (or IDLEs).
- OLT measures time difference between SSD arrival and Slot Start assigned to the ONU.
- Round-Trip Compensation (RTC) = SSD – Slot Start
- OLT sends RTC message to the ONU.
- RTC is measured for every received SSD. If drift exceeds some delta, send RTC message again.

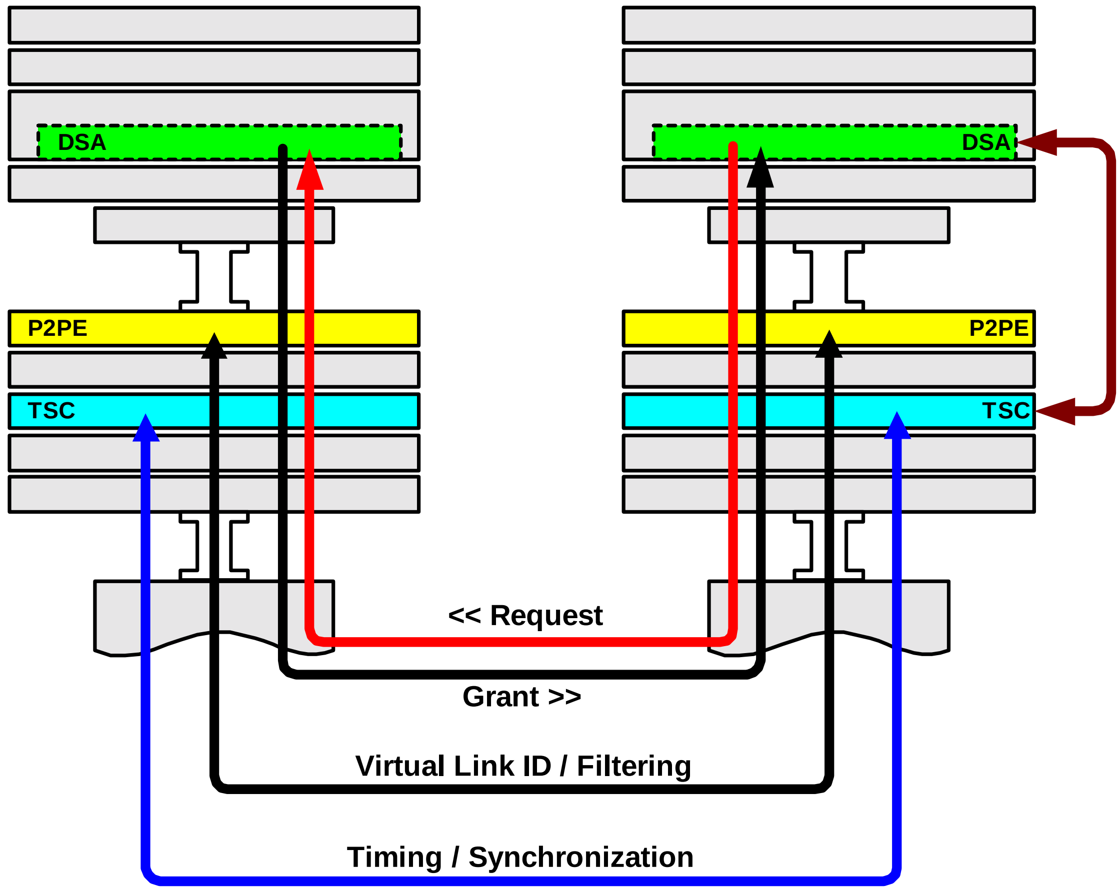
Ranging diagram



Dynamic Slot Assignment (DSA) Layer

DSA operation

- DSA layer is managed by two messages:
  - **Grant** **(OLT → ONU)**
  - **Request** **(ONU → OLT)**
- Request message is optional
- The algorithms required to send Grant and Request packets are out of 802.3 scope



Grant message

- OLT sends Grant to assign/revoke a slot to/from ONU
- Grant message is not acknowledged by ONU
- Grant is intended for a specific ONU, except Registration Grant which uses multicast destination address
- Grant message includes 4 parameters (the rest is TDB):
  - **Slot index: ONU's index of grant**
  - **Slot start: Time to begin transmission (SSD value is sent) in TQ**
  - **Slot stop: Time to end transmission (laser off) in TQ**
  - **Life Time: One-cycle or indefinite grant assignment**
- Grant with a Slot Start value of **(HEX)**FFF... identifies disabled slot (used to revoke a slot)

Request message

- ONU can send Request message reporting some changed conditions
- Format of Request message is TBD
- Request message is not acknowledged by OLT
- OLT may choose to ignore Requests

Point-to-Point Emulation (P2PE) Layer

P2PE is compatible and can be integrated with TSC and DSA to maintain support for bridging and flow control. For more information refer to a separate presentation.

Examples of bandwidth allocation schemes

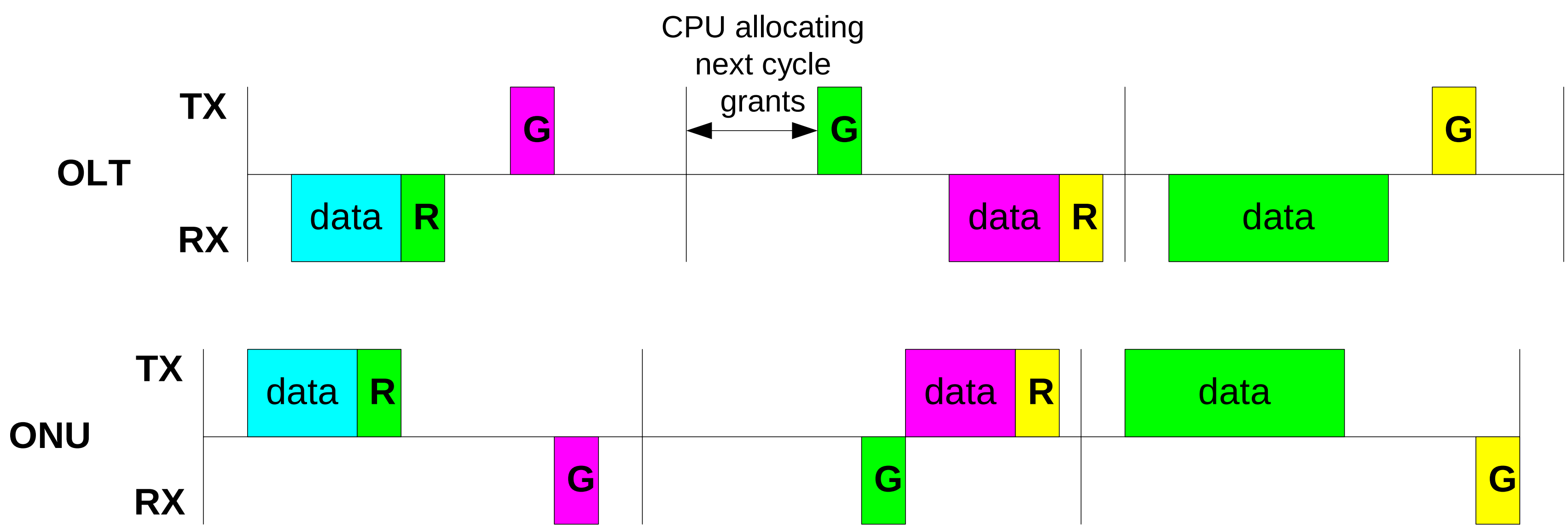
(Implemented at higher layers)

Static Bandwidth Allocation (SBA) example

- OLT ignores any ONU Requests
- OLT sends Grant with indefinite Lifetime
- Granted BW is

$$\frac{Slot\ stop - Slot\ start}{Cycle\ length} \times Line\ rate$$

Dynamic Bandwidth Allocation (DBA) example



- OLT processes Requests (scheduling) at cycle boundary
- OLT scheduling is effective from following cycle

Summary

- The heart of the protocol is in the PHY layer
- Full-duplex Ethernet should be enhanced to support gated transmission.
- The following messages must be standardized:
  - Introduction
  - Round-Trip Compensation
  - Registration Grant
  - Grant
  - Request
- Protocol provides hooks allowing higher layers to implement various bandwidth allocation algorithms