MPCP
A Simple Protocol Design

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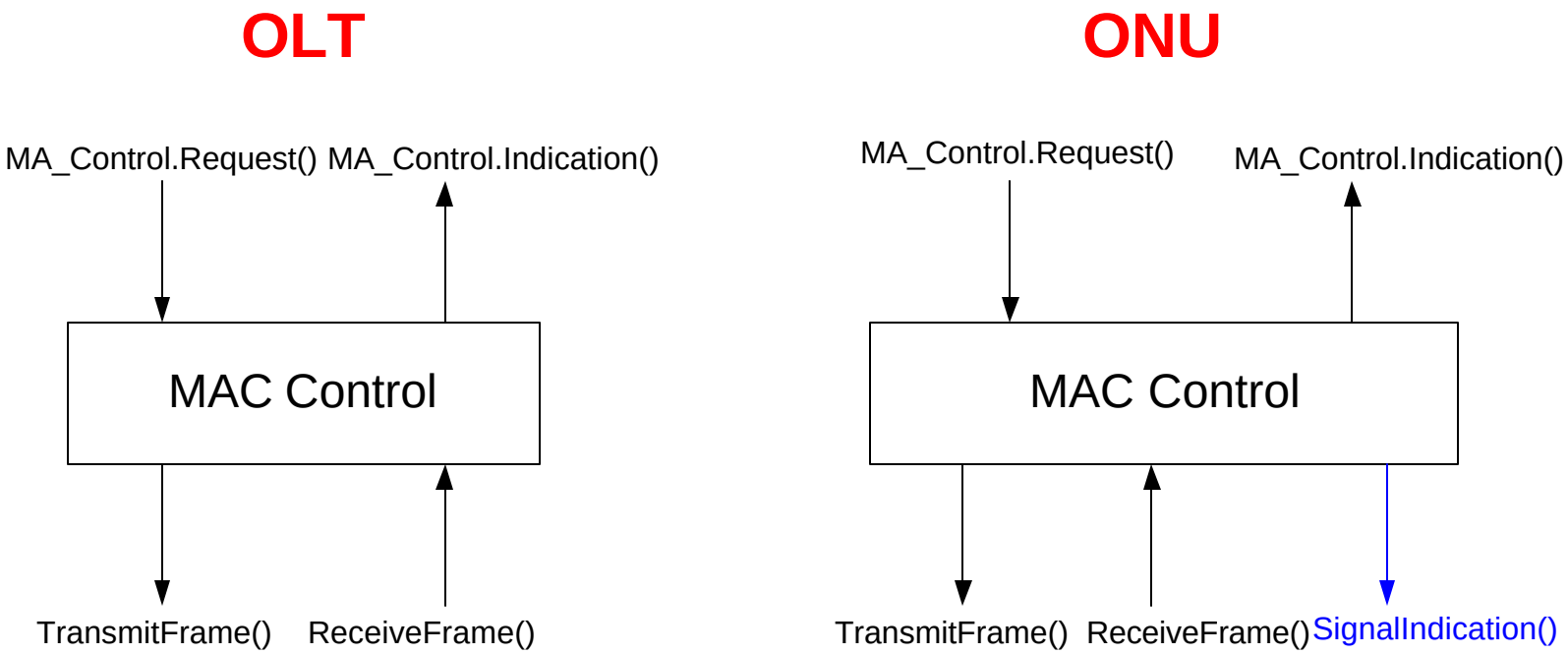
MPCP Framework



- **Multipoint extension based on MAC-control service interface and an additional SignalIndication to control burst mode**

Connecting everything™

Note: Modifications of existing operation marked in blue

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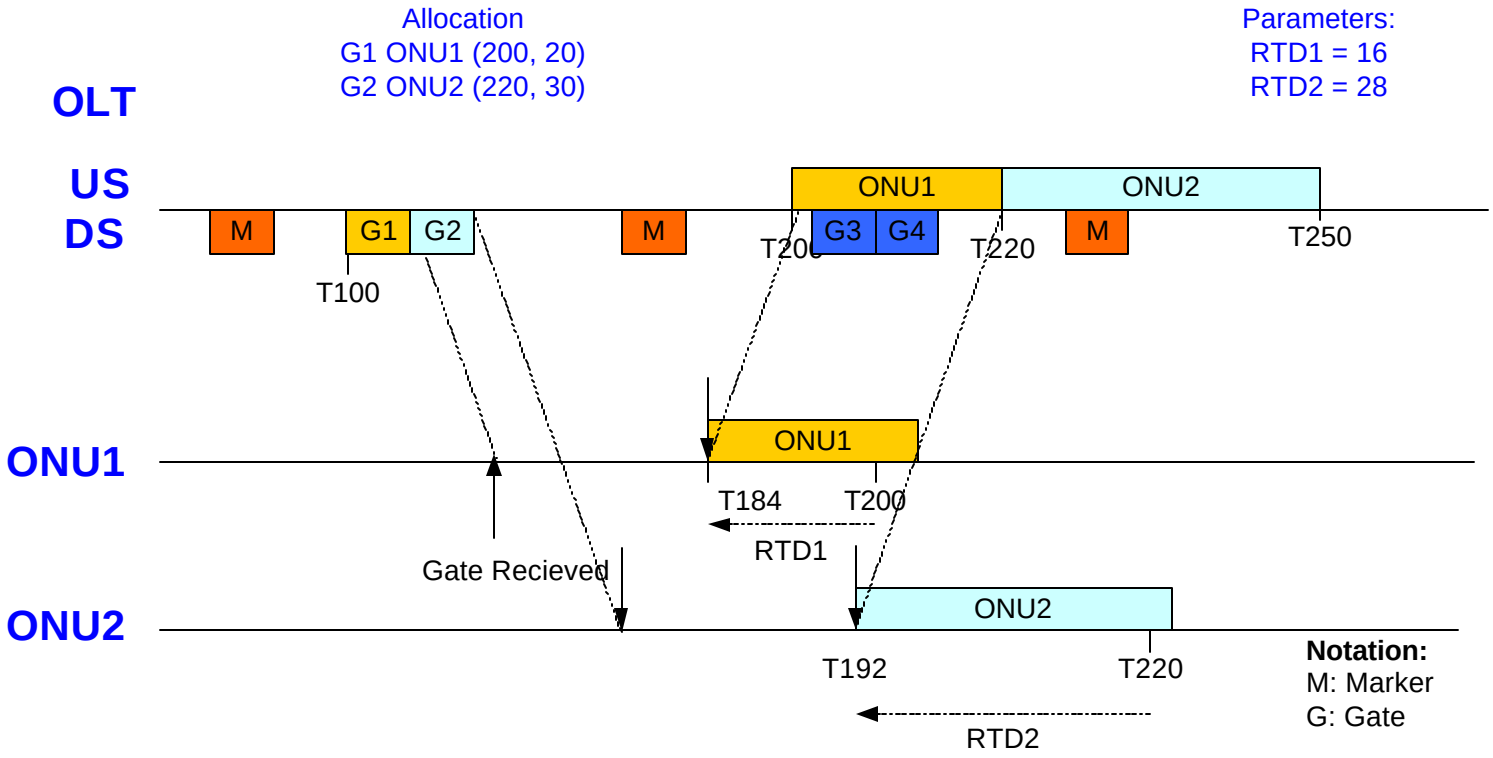
A Simple Protocol Specification

- **A simple protocol specification for the MPCP framework is presented**
  - All control operations are specified in MAC-control
    - MAC-control time reference (i.e. Marker)
    - Delay compensation
    - Gating mechanism
    - Reporting mechanism
  - All above control operations are independent and asynchronous
  - MAC-control time reference between OLT and ONU is established transparently to PHY layer

Overview System Operation



ONU Operation

- **ONU locks to downstream channel**
- **Obtains common time reference: MARKER frame**
- **Initiates auto discovery in a discovery region**
  - OLT responds with delay compensation and starts allocating bandwidth to this ONU
- **Waits for assigned allocations (i.e. gate frames)**
- **Transmits frames in assigned allocations**
  - The transmission may contain report frames to indicate the need for additional bandwidth

OLT Operation

- **Establishes a common MAC-control time reference between OLT and ONUs by sending Marker frames on downstream**
- **Assigns upstream bandwidth by sending gate allocations**
  - All recognized ONUs receive assigned gate allocations
  - Allocation policy (not specified) can be based on registration information and can optionally use reports from ONUs
  - Additional discovery gates are generated for new ONUs enter the system
- **Recognizes new ONUs transmitting in discovery regions**
  - Responds to ONU discovery requests
  - Computes ONU's compensation delay and sends it to the ONU
  - Assigns bandwidth to ONUs after discovery process

MAC-Control Specification

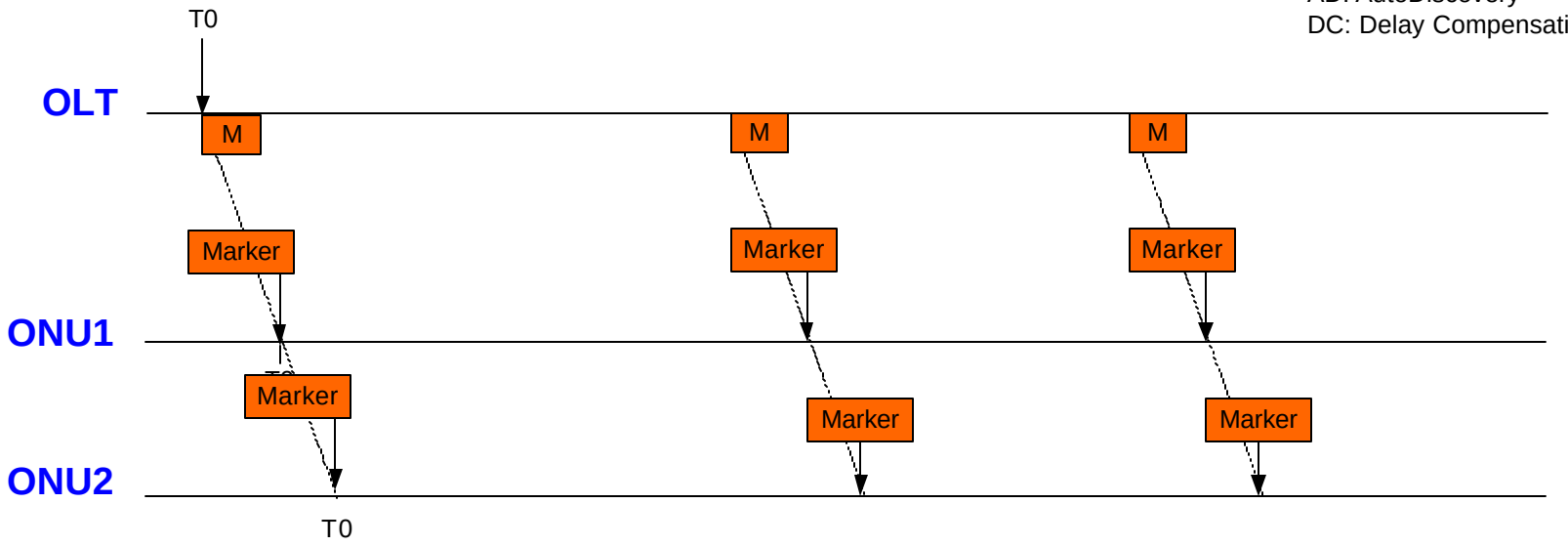
Global Transmission Reference

- **Transmission is arbitrated at the MAC-control based on common timing reference**
  - OLT MAC-control clock is the reference
  - OLT broadcasts the time reference in the Marker MAC-control frame
  - ONU MAC-control adjusts the local clock to the OLT reference
- **OLT Marker generation**
  - OLT generates this marker frequently depending on MAC-control clock drifts (particular policy does not need to be specified)
  - Marker frame is time stamped just before transmission with MAC-control clock
  - Transmission time of Marker frame from OLT to ONU should be constant
    - Any jitter should be accounted for in guardband
    - Current full duplex MAC and PHY specification and implementations have negligible jitter
- **ONU Marker reception**
  - ONU stores timestamp in a marker register used as a clock reference for transmission

Marker Operation

Allocation
Discovery (20, TBD)
Grant ONU2 (200, 30)
Grant ONU1 (230, 20)

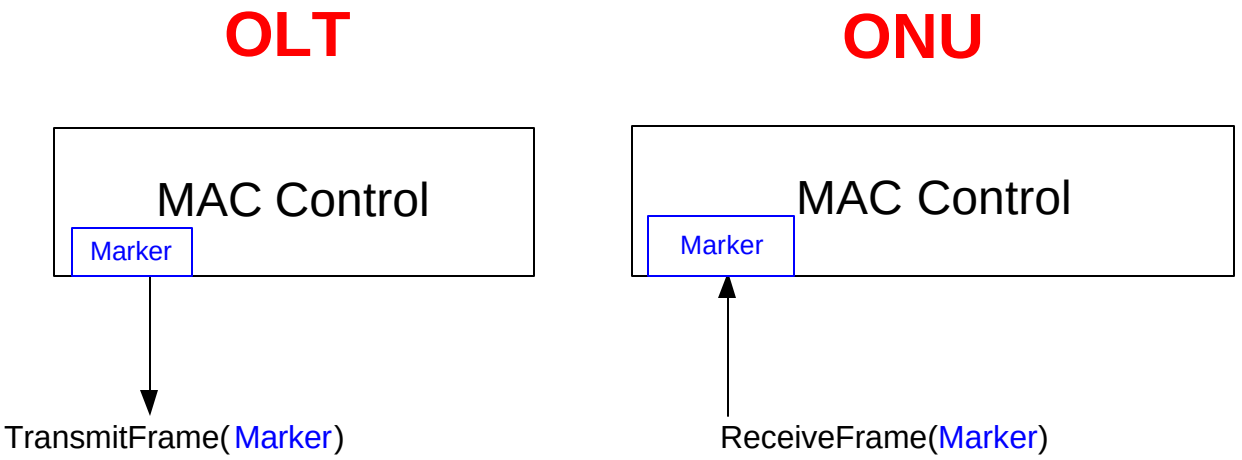
Notation:
M: Marker
G: Gate
Gx: Discovery region
AD: AutoDiscovery
DC: Delay Compensation



Parameters:
DC1 = 16
DC2 = 28

Marker establishes the time reference at MAC-control with no PHY intervention (i.e. PHY clock nor PHY synchronization)

Marker Operation Specification



Reference Transmission:

1. If (Time to Send Marker) then
    2. If (TransmitStatus==OK) // Wait for transmission
        3.1 Set Marker field with current time
        3.2 *TransmitFrame (Maker)* //Transmit frame

Reference Reception:

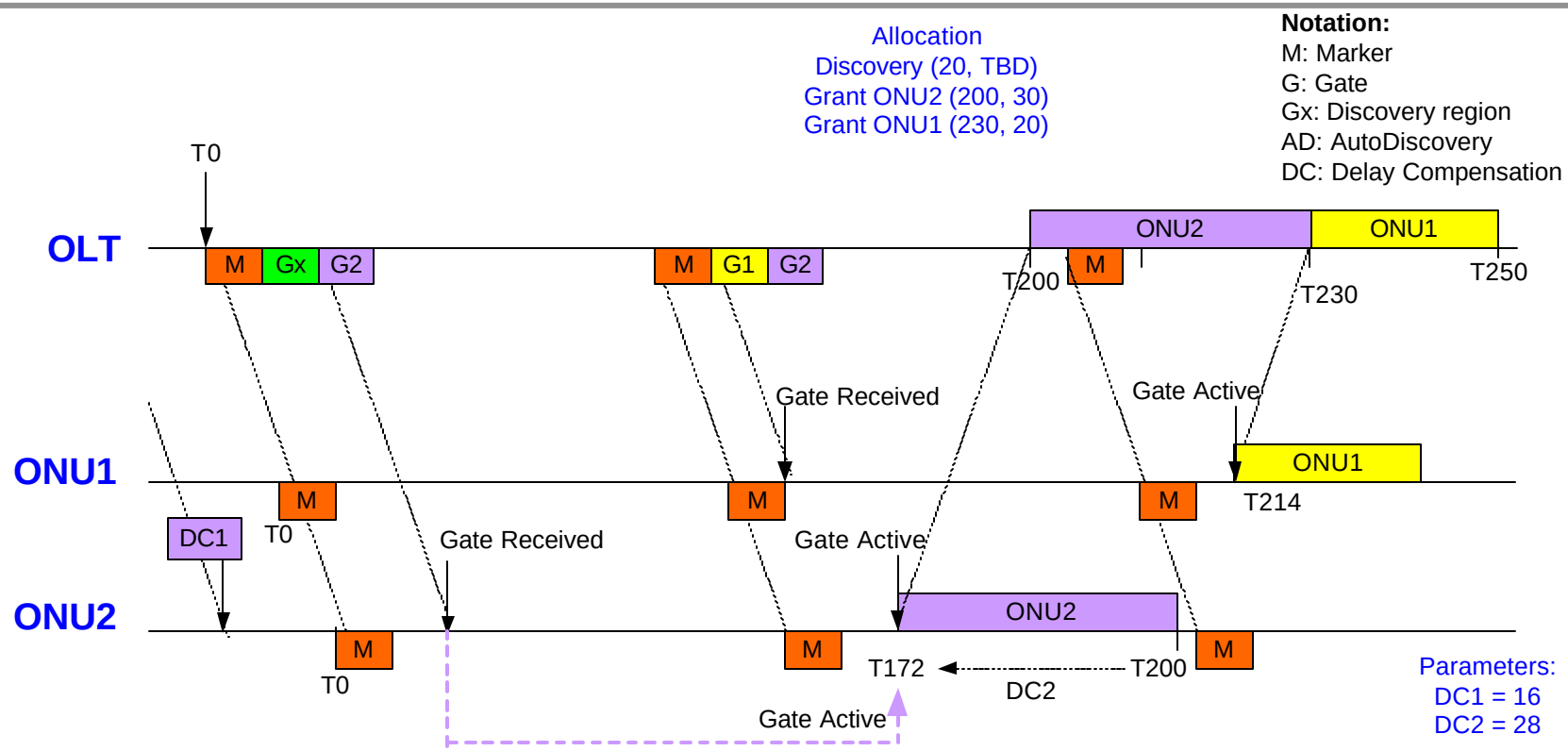
1. *ReceiveFrame(Marker)* //Receive frame
2. Override reference counter with value received

Note: Modifications of existing operation marked in blue

Gate Operation

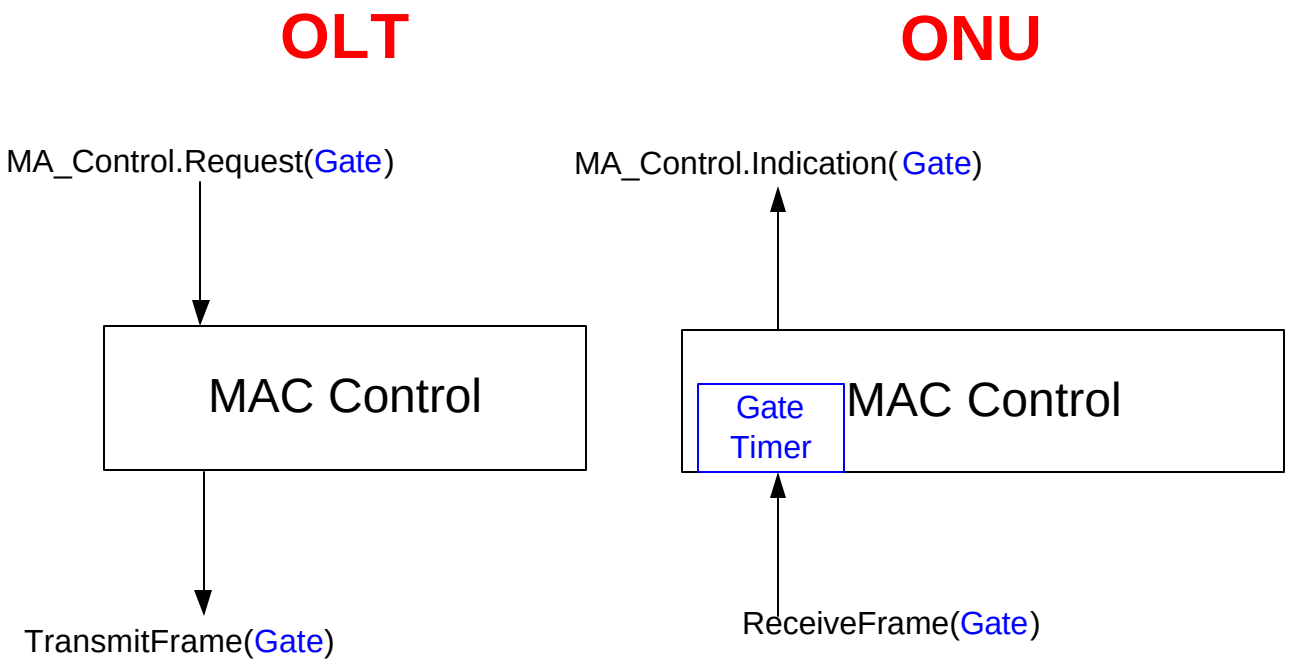
- **Gate specifies the transmission region**
  - OLT specifies all regions and each region is specified with an individual gate
  - ONUs must receive a gate to transmit in a region
    - Regions reserved for an ONU are specified with a unicast gate
    - Discovery regions are received by all allowed ONUs and specified in multicast/broadcast gates
- **Gates are generated by the OLT according to a proprietary allocation algorithm**
- **Gates are offered to the MAC-control to be built and transmitted**
  - No modifications of gate fields at this point are needed
- **There is a loosely timing relationship between the two above operations**
  - Allocator must initiate gates in advance so that it can arrive at ONU in time to be used.
  - Advance time is a constant which includes worst case delays
    - Delays of transmit, receive (i.e. MAC-control, MAC and PHY) and propagation path

Gate Operation



- **ONU can receive gate any time before it becomes active independent of marker broadcast**
- **Independent gate transmission and marker transmission and upstream data transmission in gate region**
- **No constraints to time gate and marker transmission on downstream**

Gate Operation Specification



Grant Transmission:

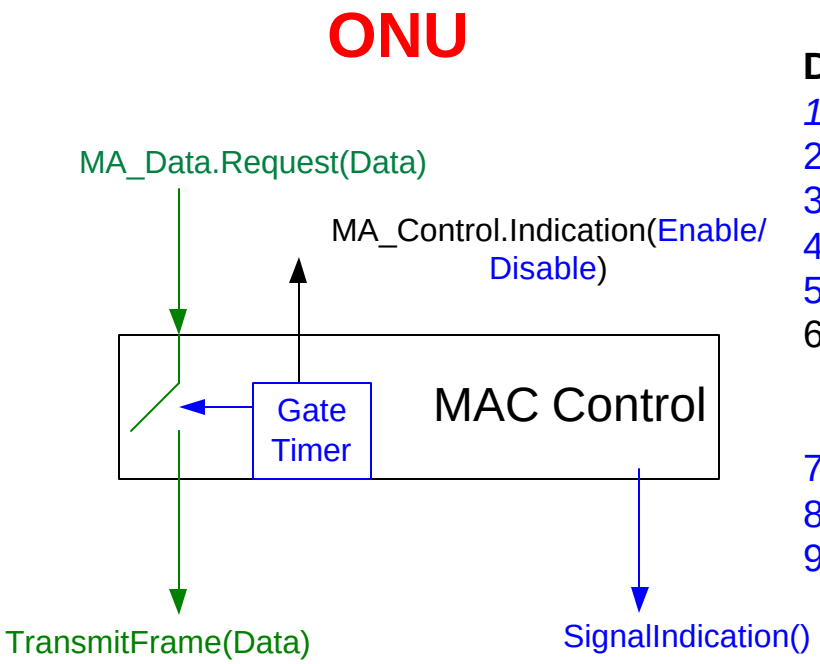
1. *MAC_Control.Request (Gate)* //Receive gate frame
2. If(TransmitStatus==OK) // Wait for current transmission to terminate
   2.1. *TransmitFrame (Gate)* //Transmit Gate frame

Grant Reception:

1. *ReceiveFrame(Gate)* //Receive gate frame
2. Store Gate
3. Set (Open) Gate timer

Note: Modifications of existing operation marked in blue

ONU Data Transmission



Data Transmission:

1. *Timeout of (*Open) Gate
2. *SignalIndication(ON) //*Turn on Laser
3. Set (Close) Gate timer
4. *MA_Control.Indication(Disable)* //Disable client
5. Wait laser turn on time(*)
6. Transmit Frames as delivered by client (data or control):
   MA_Data.Request(Frame) or MA_Control.Request(Frame)
   TransmitFrame(Frame)
7. Timeout of (Close) Gate
8. *MA_Control.Indication(Enable)* //Enable Client
9. *SignalIndication(OFF) //*Turn off laser

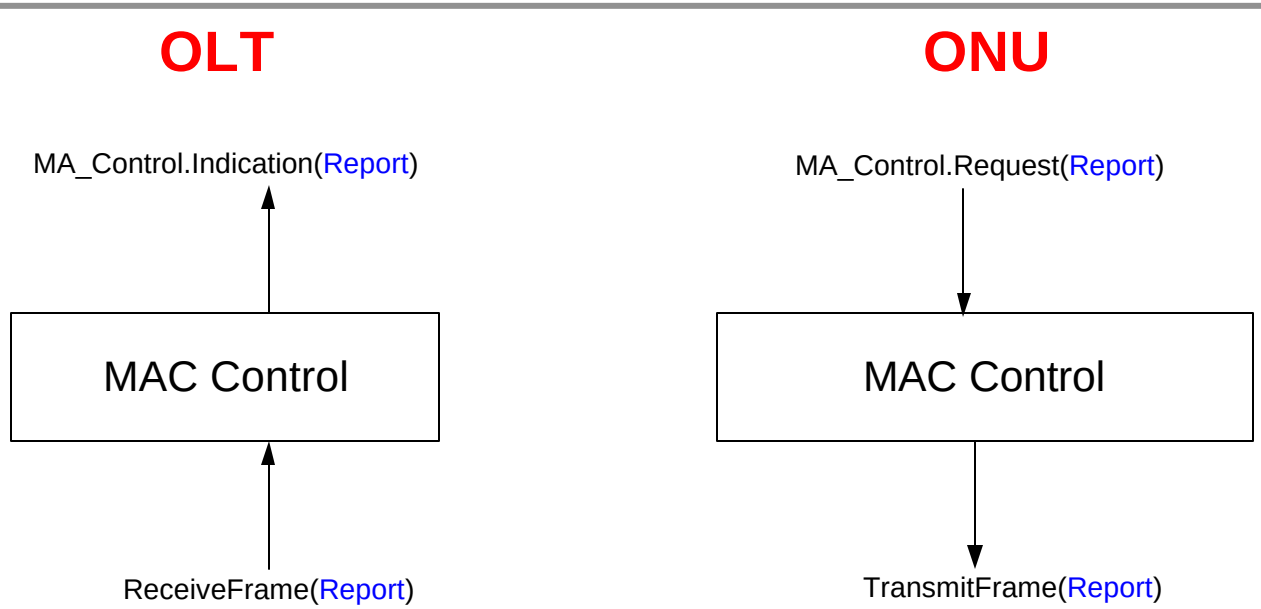
(*) Laser turn on/off time is a constant configuration parameter

Note: Modifications of existing operation marked in blue
Data path marked in Green.

Report Mechanism

- **ONU generates reports to assist the OLT allocation decisions**
- **Reports are generated in the MAC-client and processed at the MAC-control and MAC-control client**
- **Reports are optional**

Report Operation



Report Reception:

1. *ReceiveFrame(Report)* //Receive frame
2. MA_Control.Indication(*Report*) // Pass report

Report Transmission:

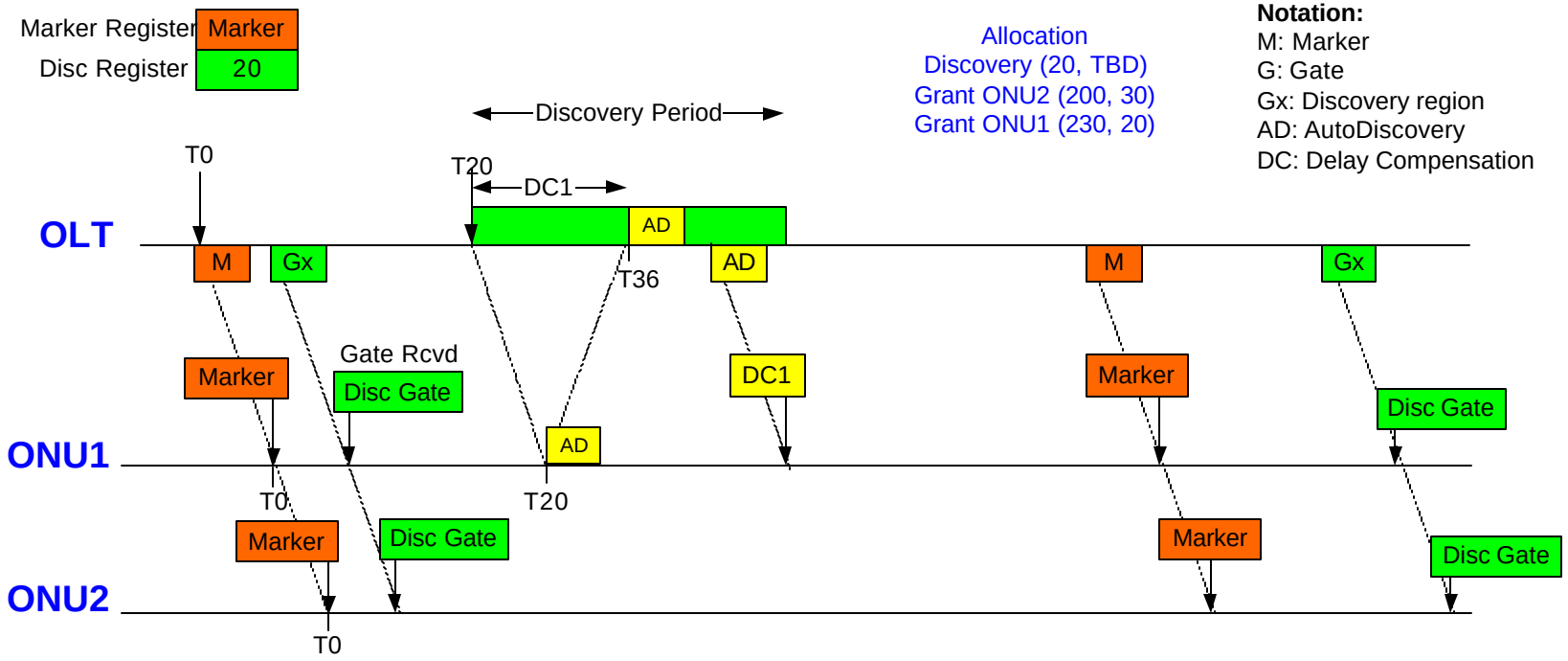
Same process as data frame transmission in Slide 7 except that the frame transmitted is a control frame

Note: Modifications of existing operation marked in blue

Auto Discovery

- **During auto discovery several initialization operations are performed:**
  - Registered the ONU
  - Compute ONU delay compensation
- **Auto discovery occurs in discovery regions (i.e. a particular type of gate)**
- **Data transmission in a discovery region:**
  - Only a discovery request frame can be transmitted in a discovery region
  - The frame must be transmitted at the beginning of the region so that delay compensation can be measured
- **Discovery regions can be**
  - Multicast to allow new ONUs to enter the system
    - These regions require big guard-bands
  - Unicast to request a given ONU to repeat discovery
    - Used by the OLT to periodically measure the delay compensation
    - Guard band of these regions can be much smaller (almost normal size)

Auto Discovery

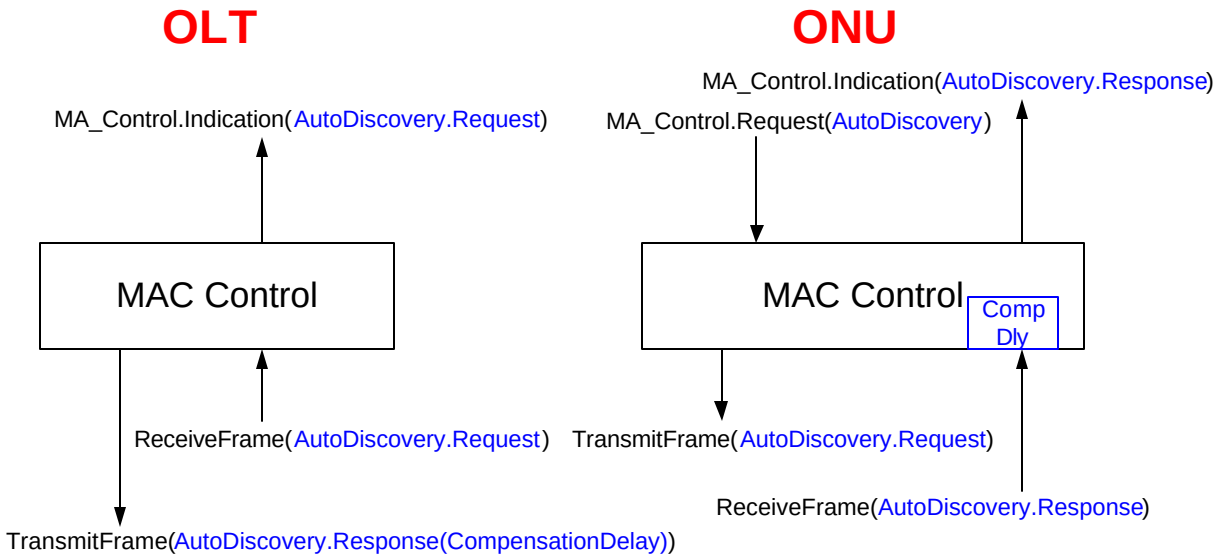


- **Discovery gates are specified and announced by OLT**
  - OLT remembers discovery start time to compute delay compensation

Parameters:
DC1 = 16
DC2 = 28

- **ONU stores discovery gate**
  - It must use and initiate discovery in unicast discovery regions (used to frequently refine delay compensation)
  - Multicast discovery regions are used when no unicast ones are available

ONU Auto Discovery



1. **OLT specifies Discovery regions with the gate frames. ONU initiates Auto Discovery in Discovery regions**
2. **OLT recognizes the ONU and responds with CompensationDelay value, and possibly additional information**
3. **If ONU does not receive response, it tries again in the following discovery regions**
4. **OLT generates a stream of grants for all recognized ONUs**
5. **ONU transmits in assigned grants from now on**

Connecting everything™

Note: Modifications of existing operation marked in blue

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Summary

- **A simple mechanism with flexible control has been presented**

- **The simplicity comes from:**
  - All operations are independent and asynchronous :
    - Timing reference
    - Message transmission
    - Allocation mechanism
    - Reporting mechanism
  - Uniformity of the specification
    - All operations occur at the MAC control transparently to PHY and MAC layers