2D Scheduling for 100G EPON

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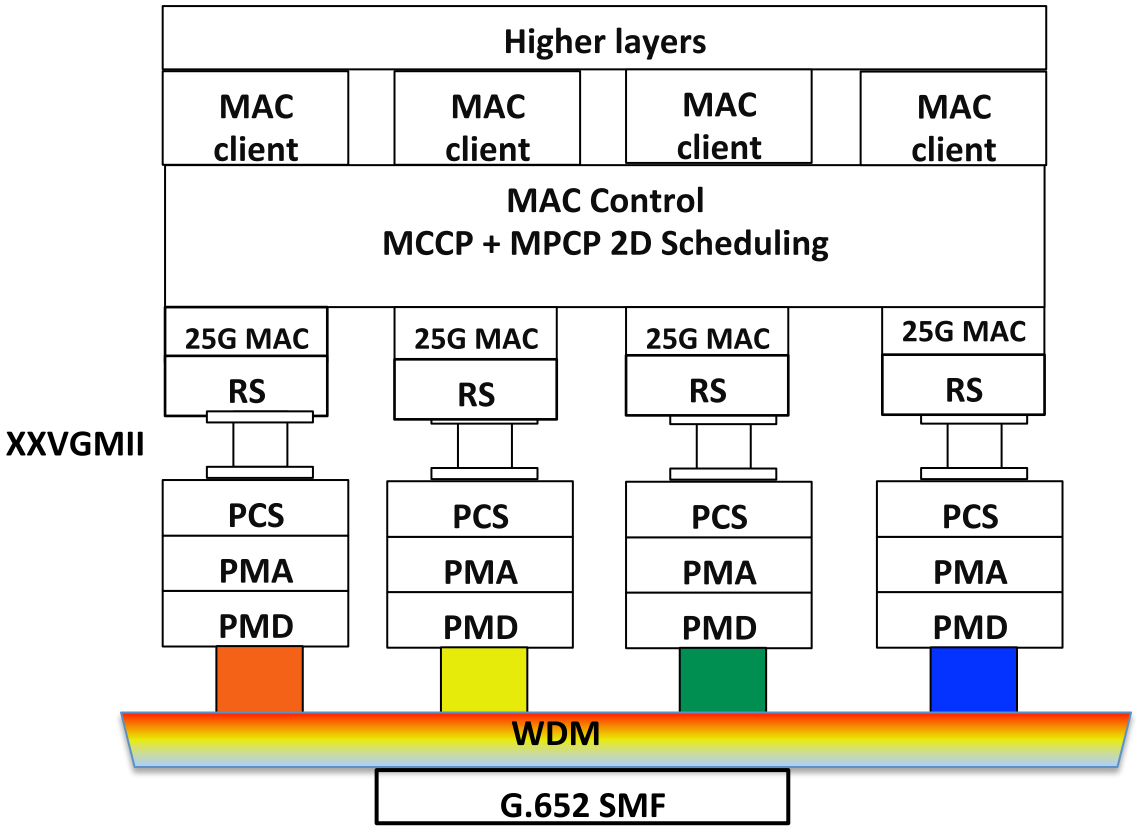
Outline

- Background
- 1D and 2D scheduling
- 2D scheduling model for fixed frames
- 2D scheduling for variable frames
- Frame boundary aware MPCP report

Background

- Logical MAC layer channel bonding was proposed at the Atlanta meeting (dai_3ca_01_0116.pdf)
- MAC control sub-layer channel bonding with MPCP+ was proposed at the Macau meeting (kramer_3ca_2a_0316.pdf)
- MAC control sub-layer channel bonding with Multiple-Channel Control Protocol (MCCP) was proposed at the Macau meeting (dai_3ca_3b_0316.pdf)
- Both MPCP+ and MCCP are MAC control sub-layer channel bonding
- This contribution further discusses using 2D scheduling mechanisms for MCC (upstream channel bonding)

100G EPON MCCP Channel Bonding Model

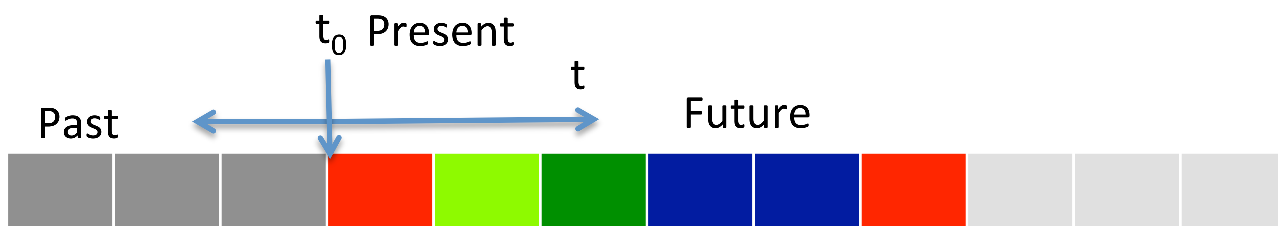


- Channel bonding is achieved with Multi-Channel Control Protocol
- MCCP works with MPCP to achieve channel bonding
- Using four identical 25G lanes

MCCP + MPCP is equivalent to two dimensional scheduling

One Dimensional Scheduler

- EPON and 10G EPON use 1D scheduling in the time domain
- The unit in time is represented as Time Quanta (TQ)
- One TQ = 16ns transmission time at the given rate

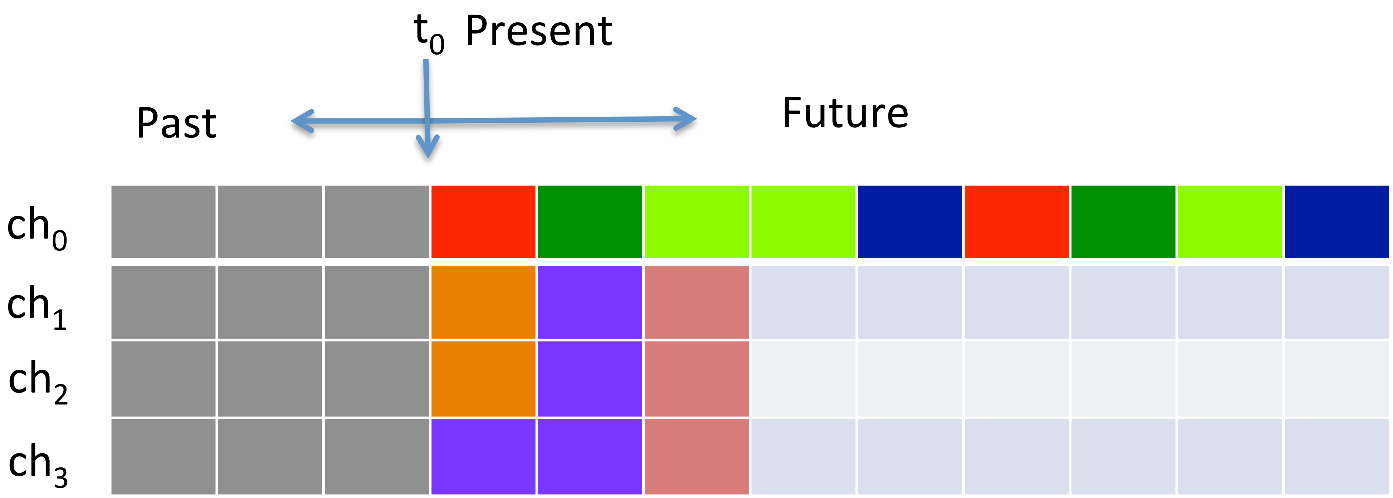


A 1D Grant can be expressed as:

$$G\ (t_i, n)$$

where t_i is the future transmission start time, and n is the number of TQs been granted

Two Dimensional Scheduler



A 2D Grant can be expressed as:

$$G\,(ch_{j,}\ t_i,\ n_j\ )$$

Total granted bandwidth in TQ = $\sum_j n_j$,

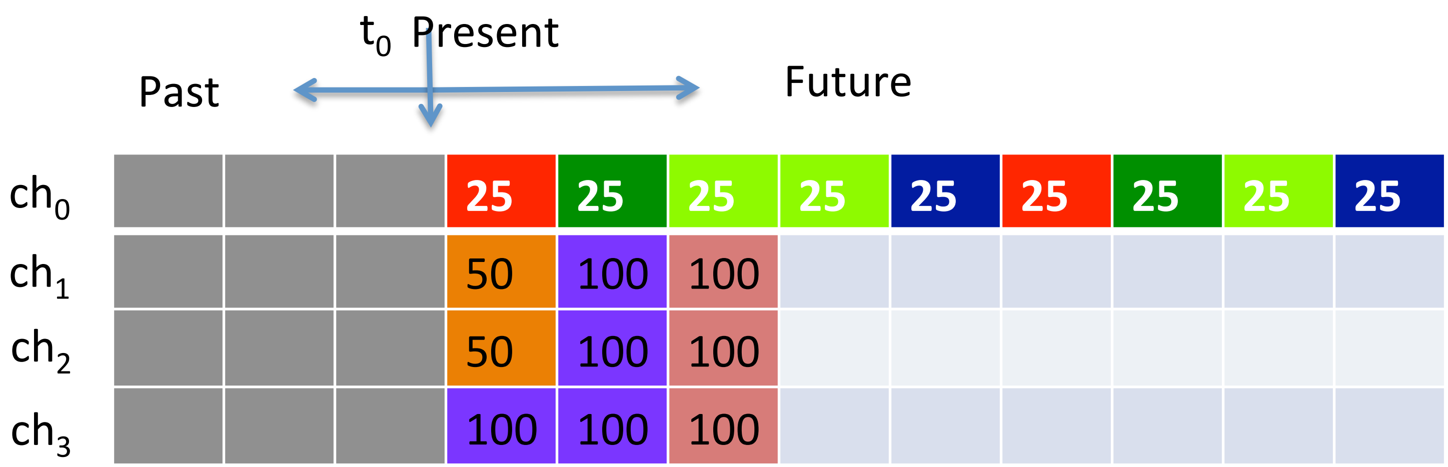
where ch_j (j = 0, 1, 2, 3) is the channel ID, t_i is the future transmission start time for ch_i, and n_j is the number of TQs been granted to ch_i

2D Scheduling for fixed frames

- To simplify discussion, we'll first discuss a fixed frame scenario.
- ATM is an example of fixed frame protocol
- We further assume that the length of a grant equals to the length of a frame

n x TQ = Length of a frame.

A frame or n x TQ is represented by symbol : 



An example of a 2D scheduling for 25G, 50G and 100G ONUs

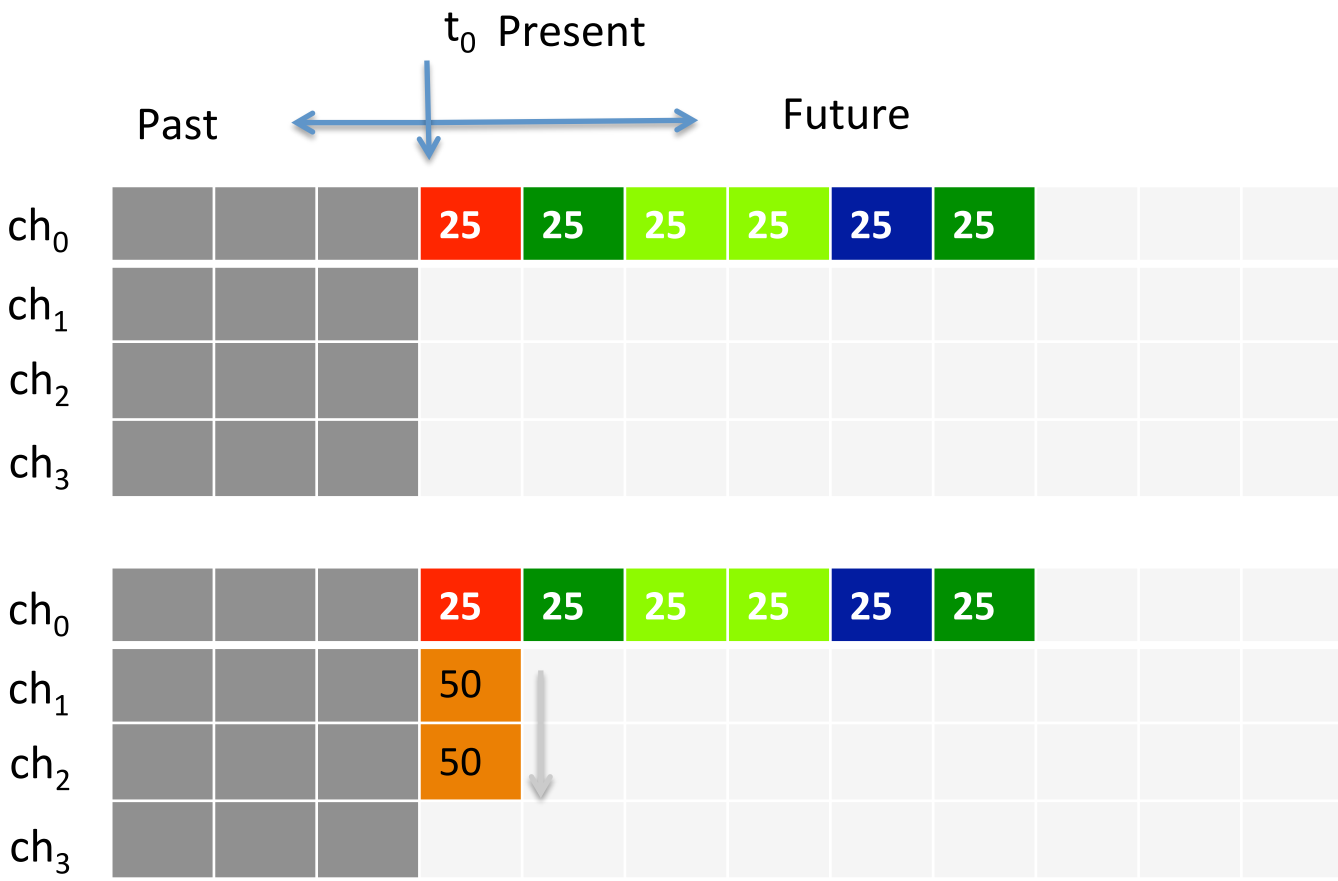
2D Scheduling Rules for ONU

1. An ONU reports its channel capacity, ie., 4 channels, 2 channels or 1 channel in a MPCP report message
2. An ONU reports it lane/channel configuration if dynamic channel configuration is enable d(tunable, or power saving mode)
3. An ONU reports its total transmission data buffer (for all channels) in a MPCP report message

2D Scheduling Rules for OLT

1. The 2D scheduler searches for the earliest available channel beyond present time t_0
2. The 2D scheduler sends a grant $G(ch_j, t_{l,}, n_j)$ or grants for the first available ch_j to the ONU
3. If multiple channels are available at t_l, a grant or grants will be sent for each channel
4. If more than one channel is available for a given $t_{l,}$ the channel with a different index from the immediate previous channel will be chosen first (for traffic balance)
5. The 2D scheduler continues to search for the earliest available channels until finishing grants for the ONU

2D Scheduling Example 1

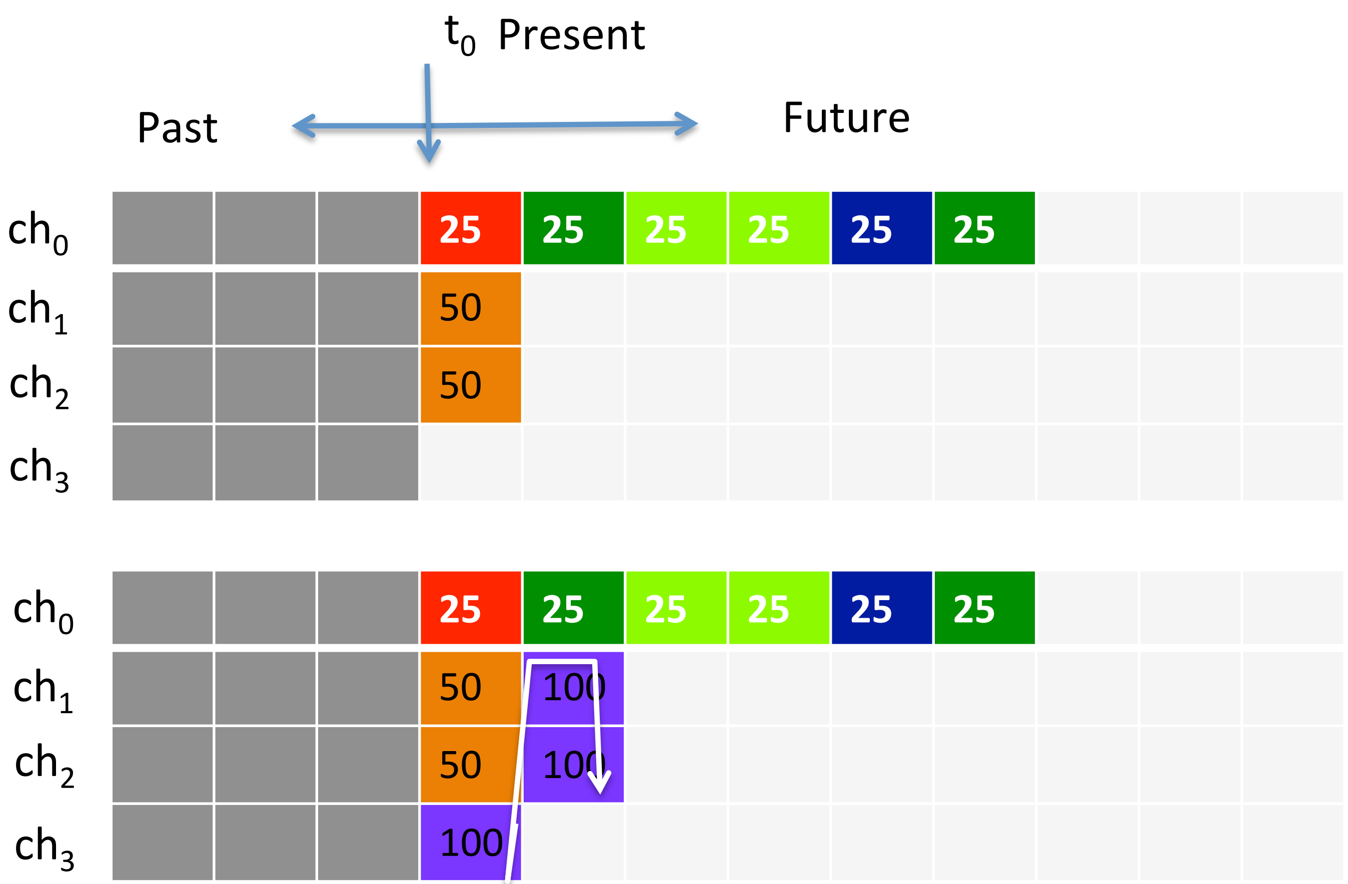


- Assuming 25G ONUs are assigned to lane 0 only
- 50G ONUs are assigned to line 1 and 2
- 100G ONUs are assigned to line 0 to 3.

OLT Rule 2: The 2D scheduler sends a grant $G(ch_k, t_{l,}, n)$ or grants of the first available ch_j to the ONU

OLT Rule 3: If multiple channels available at t_l, each channel will send a grant or grants.

2D Scheduling Example 2



- Assuming 25G ONUs are assigned to lane 0 only
- 50G ONUs are assigned to line 1 and 2
- 100G ONUs are assigned to line 0 to 3.

OLT Rule 4: If more than one channel is available for a given $t_{l,}$ the channel with a different index from the immediate previous channel will be chosen first

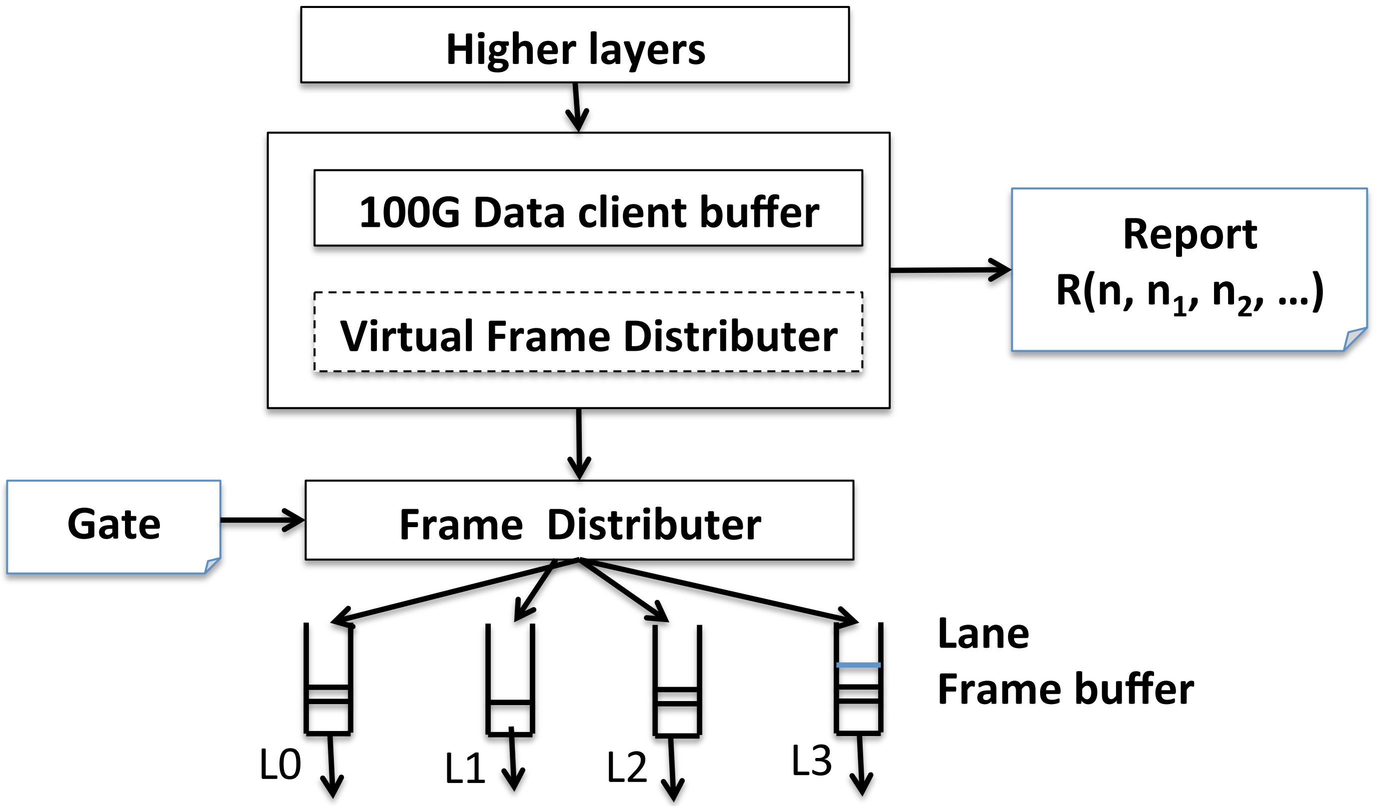
2D Scheduling for variable length frames

- Ethernet frames are variable in lengths.
- However, the 2D scheduling mechanism works for variable length frames as well
- In a variable frame protocol, such as Ethernet, the length of a grant n_j for a ch_J may NOT equal the length of the Ethernet frames to be transmitted on ch_j

$$n_j \times TQ \neq \text{Length of Ethernet frames for } ch_j.$$

Channel bonding for variable length frames can be addressed with the fragmentation or acceptance of a efficiency trade off (to be discussed in a separated contribution).
We'll discuss another approach here.

Virtual Frame Distributer



- Virtual frame distributer searches for frame boundaries for the frames to be distributed to the lane buffers
- Frame distributer actually distributes frames to the lane buffers

Frame boundary aware MPCP report

Frame boundary aware MPCP Report:

$R(n, n_1, n_2, \ldots,)$,

Where n is the total data client buffer depth,

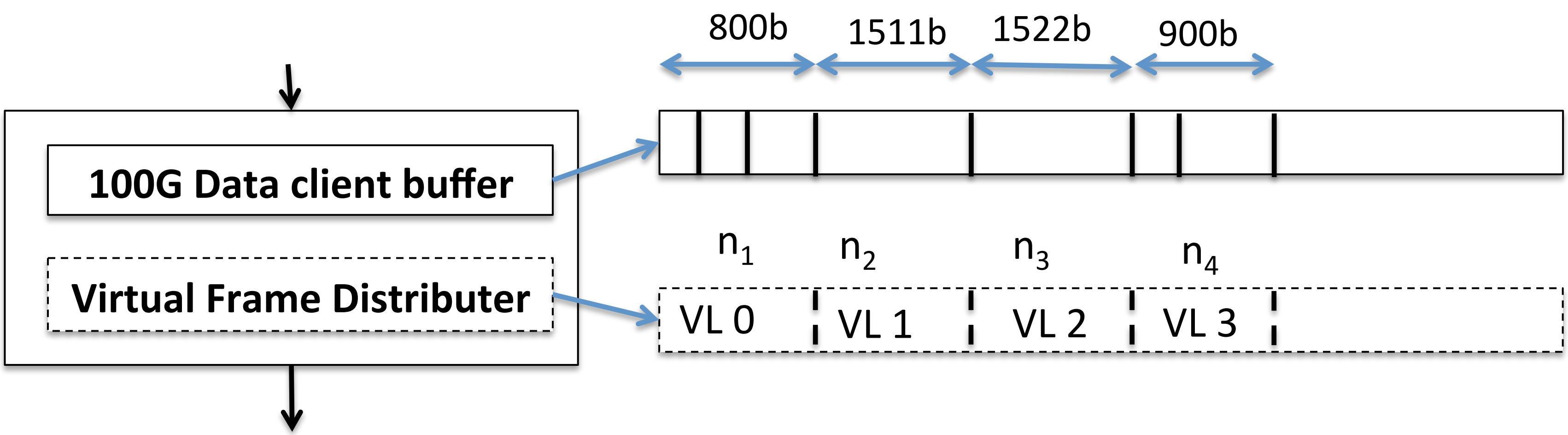
n_1 is the frame boundary of the frame <= 1522 bytes from the botterm of the buffer,

n_2 is the frame boundary of the frame <= 1522 start from the previous frame boundary,

n_3 ...

- The unit of n, n1, n2, could be bit, byte or TQ
- n is not independent, n = sum of n_j.

Example of frame boundary aware MPCP report



Report: R(n, n_1, n_2, …)

where n_1 = 800 bytes, n_2 = 1511 byte, n_3 = 1522 bytes, n_4 = 900 byte. $n = n_1 + n_2 + n_3 + n_4$. VL represents a virtual lane buffer.

- We have assumed the maximum lane buffer = maximum Ethernet frame size

OLT 2D scheduling for variable length frames

Additional rule for 2D scheduling of variable length frames:

Rule 6. When the 2D scheduler receives the report from an ONU, $R(n, n_1, n_2, \ldots)$,

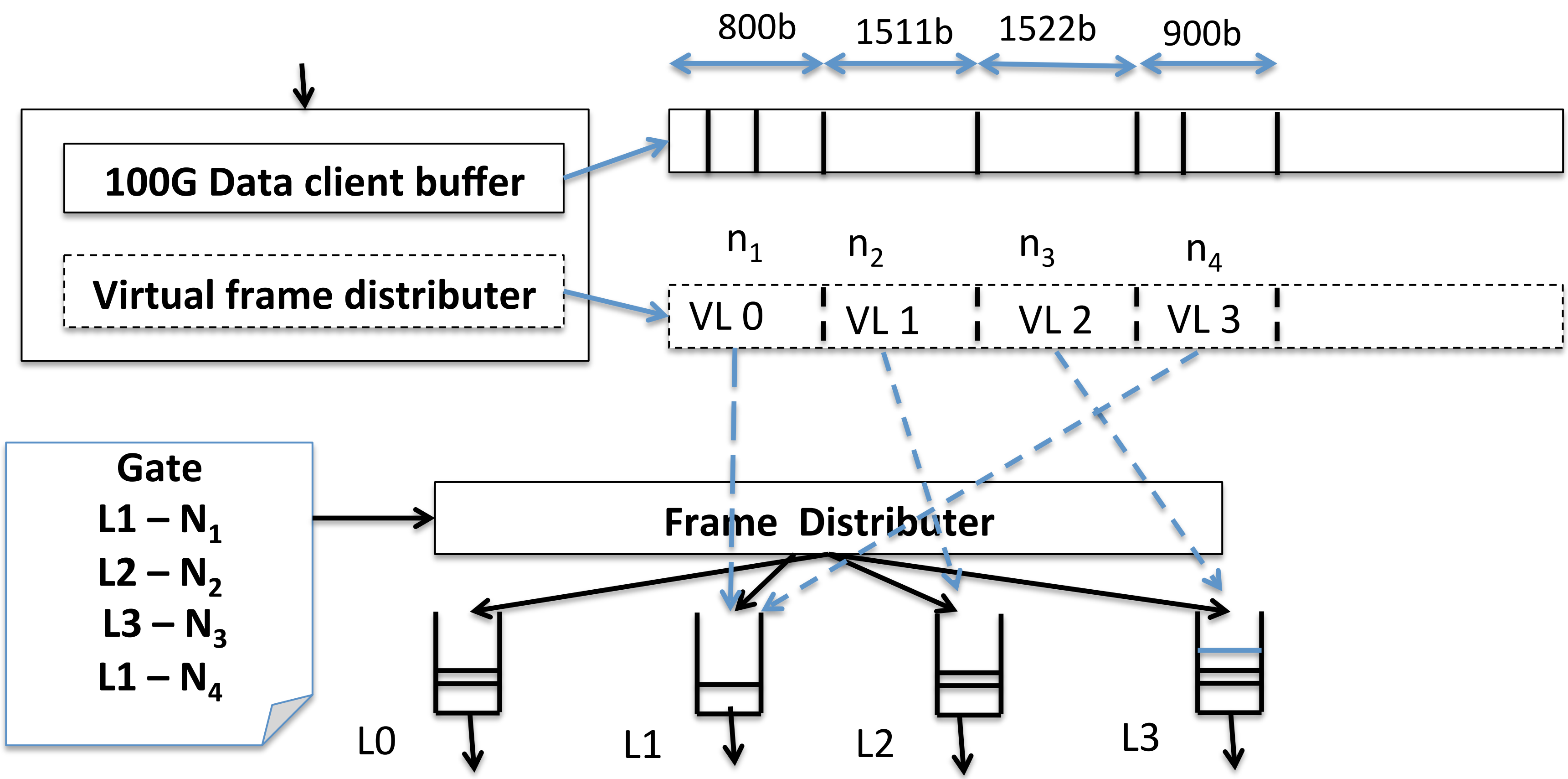
it first maps requested bandwidth into grants in the unit of TQ:

$n \rightarrow N$, $n_1 \rightarrow N_1$, … (PHY layer overheads are condisered).

Then, the OLT assigns Grants according 2D scheduling rules, for example:

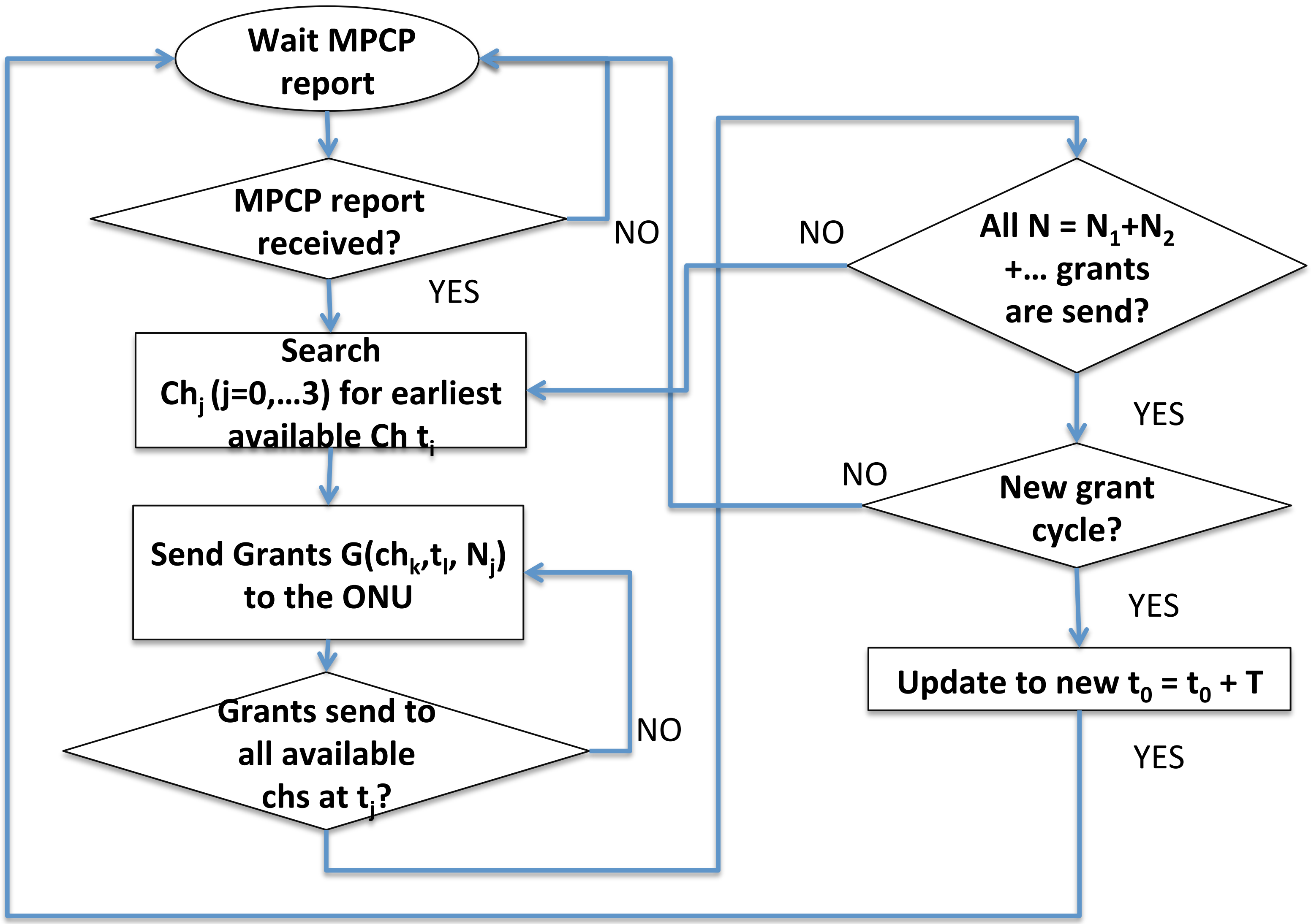
$G(ch_1, N_1,)$, $G(ch_2, N_2)$, $G(ch_3, N3)$, $G(ch_1, N4)$

Example of frame boundary aware MPCP report



- Time info was not shown since the example is for the order of frame distribution

2D Scheduling State Machine



Dynamic Channel Bonding with 2D Scheduler

ONU rule 2: An ONU reports it lane/channel configuration if dynamic channel configuration is enable (tunable, or power saving mode)

- Dynamic channel bonding can be achieved by applying 2D scheduling ONU rule #2.
- 50G and 100G ONUs can go into power saving mode by report only active lanes in MPCP reports
- With tunable optics or color management, the 25G ONUs and 50G ONUs can be assigned to any lanes for efficiency in lane utilization or traffic balance

Conclusions

- The 2D scheduling mechanism works for both fixed frame protocols and variable frame Ethernet
- The Frame-boundary-aware MPCP report enables efficient 2D scheduling over channels bonded to 100G EPON without fragmentation
- The 2D scheduling mechanism supports dynamic channel bonding

Thanks

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