Granting in a multi-lane environment

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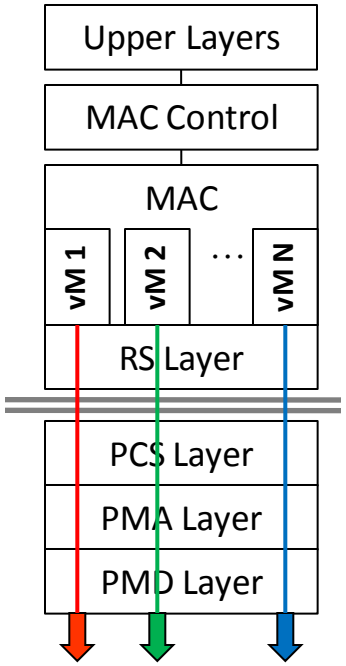
How should we grant bonded channels

- **Two Options;**
  - Grant all lanes together
  - Grant each lane independently



Issues with granting all lanes together

- **Implies synchronization between US bonded channels**
  - Minor issue
- **Can result in wasted capacity**
  - Due to Grant sizing as required by TQ
  - Due to Grant sizing due to multi-lanes
- **Possible Generational issues**

Issues with granting all lanes together

- **Capacity loss due to TQ**
  - Assuming TQ = 16 ns & FEC = RS(255,223)

    What is min Grant size Bytes?
    - **Min frame = 64B, IPG = 12B**
    - **Min Pkt = 76B which required 2 64B/65B blocks or 130B**
    - **FEC + = 32B**
    - **Total = 162B**
  - ~1/3 of IP traffic has PDU of ≤ 52B!

    But only ~2.0% by volume

Rate (Gb/s	162 Bytes (ns)	TQs	Min Grant (Bytes)	OvrHd
10	129.6	9	180	11.1%
25	51.84	4	200	23.5%
50	25.92	2	200	23.5%
100	12.96	1	200	23.5%

Issues with granting all lanes together

- **Capacity loss due to multi-lane granting**
  - If unbonded ONU is using 1 of N channels other N-1 channels may not be usable (4 examples on next slide)
    - **All 4 transport same data capacity with various levels of efficiency**
    - **All 4 have 1 ONU with 4 bonded chs, 2 ONUs with 2 bonded chs and 5 non-bonded ONUs**
    - **Ex 1, 2 & 3 grant all lanes together**
    - **Ex 4 grant lanes independently**

ONUModels

Model 100	Lane A, non-bonded
Model 201	Lanes A & B bonded
Model 202	Lanes C & D bonded
Model 400	4 bonded lanes

Models per Example

ONU	Ex 1	Ex 2	Ex 3	Ex 4
ONU 1	400	400	400	201
ONU 2	201	201	202	201
ONU 3	201	202	202	201
ONU 4	100	100	100	100
ONU 5	100	100	100	100
ONU 6	100	100	100	100
ONU 7	100	100	100	100
ONU 8	100	100	100	100
Models	3	4	3	2

Example 1			
Land A	Lane B	Lane C	Lane D
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
2	2	-	-
2	2	-	-
2	2	-	-
2	2	-	-
3	3	-	-
3	3	-	-
4	-	-	-
4	-	-	-
5	-	-	-
5	-	-	-
6	-	-	-
6	-	-	-
7	-	-	-
8	-	-	-

	Capacity	
ONU	Grntd	Rqst
1	16	13
2	8	7
3	4	3
4	2	2
5	2	2
6	2	2
7	1	1
8	1	1
Unts Grntd	36	31
Total Capacity		72
Unused Capacity		41
Efficiency		**43.1%**
Statistical Gain		**Fair**

Example 2			
Land A	Lane B	Lane C	Lane D
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
2	2	3	3
2	2	3	3
2	2	-	-
2	2	-	-
4	-	-	-
4	-	-	-
5	-	-	-
5	-	-	-
6	-	-	-
6	-	-	-
7	-	-	-
8	-	-	-

	Capacity	
ONU	Grntd	Rqst
1	16	13
2	8	7
3	4	3
4	2	2
5	2	2
6	2	2
7	1	1
8	1	1
Unts Grntd	36	31
Total Capacity		64
Unused Capacity		33
Efficiency		**48.4%**
Statistical Gain		**Fair**

Example 3			
Land A	Lane B	Lane C	Lane D
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
4	-	2	2
4	-	2	2
5	-	2	2
5	-	2	2
6	-	3	3
6	-	3	3
7	-	-	-
8	-	-	-

	Capacity	
ONU	Grntd	Rqst
1	16	13
2	8	7
3	4	3
4	2	2
5	2	2
6	2	2
7	1	1
8	1	1
Unts Grntd	36	31
Total Capacity		48
Unused Capacity		17
Efficiency		**64.6%**
Statistical Gain		**Fair**

Example 4			
Land A	Lane B	Lane C	Lane D
1	1		
1	1		
1	1		
1	1		
1	1		
1	1		
1	2		
2	2		
4	2		
4	2		
5	2		
5	2		
6	-		
6	3		
7	3		
8	3		

	Capacity	
ONU	Grntd	Rqst
1	13	13
2	7	7
3	3	3
4	2	2
5	2	2
6	2	2
7	1	1
8	1	1
Unts Grntd	31	31
Total Capacity		32
Unused Capacity		1
Efficiency		**96.9%**
Statistical Gain		**Good**

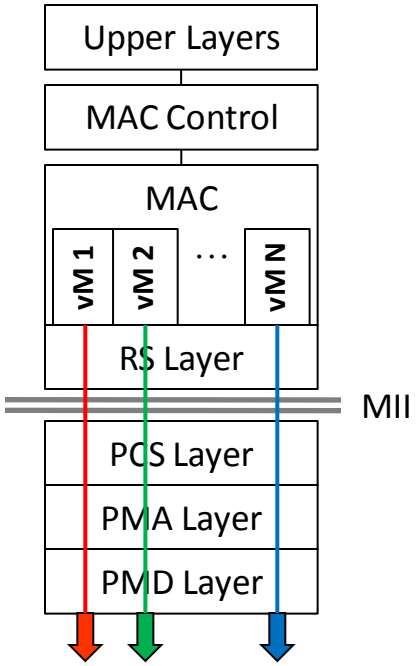
Additional examples in backup

Issues with granting all lanes together

- **Generational issues**
  - This is more of a downstream issue
    - **If bonding is done in PCS cannot mix & match ONUs with different levels of bonding as data will always be spread over multiple lanes**
  - In the upstream direction the OLT could potentially run separate PHYs for bonded/unbonded ONUs alleviating the issue

How to allow for independent granting

- **Currently in ONU 1 LLID == 1 MAC**
- **Ideally we want to create virtual MACs that all have the same MAC Address but only send frames to a single lane.**
  - Enforce 1 LLID per vMAC but the higher level MAC can now be serviced by N LLIDs instead of just one.
  - Each LLID can be granted independently
  - Easy to mix & match ONUs with 1, or 2, or N bondable channels.



Cl 77.1.2 has some interesting wording

- **From Cl 77.1.2**

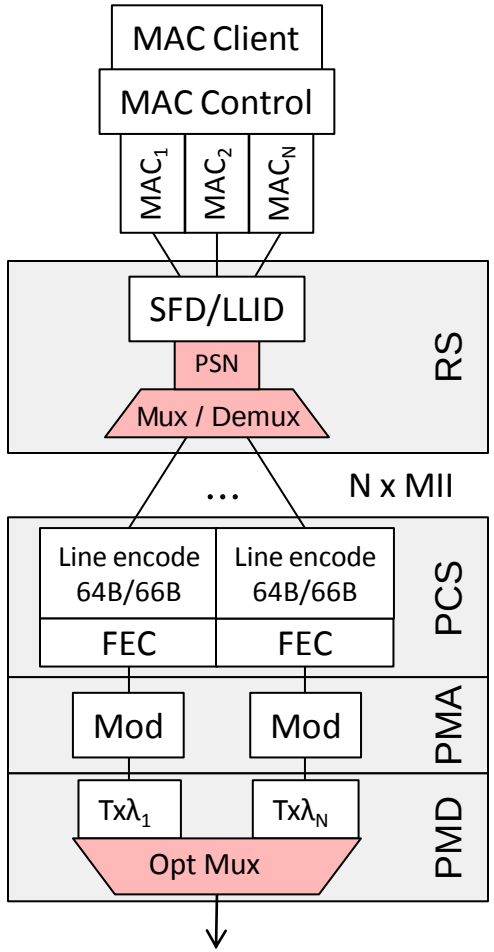
  The ONU only requires one MAC instance since frame filtering operations are done at the RS layer before reaching the MAC. Therefore, MAC and layers above are emulation-agnostic at the ONU (see 76.2.6.1.3).
  Although Figure 77–2 and Figure 77–3 and supporting text describe multiple MACs within the OLT, a single unicast MAC address may be used by the OLT. Within the EPON Network, MACs are uniquely identified by their LLIDs, which are dynamically assigned by the registration process.

- **Perhaps we can use this to our advantage?**
- **There is also an interesting note in 77.3.6**

  b) Source Address (SA). The SA in MPCPDU is the individual MAC address associated with the port through which the MPCPDU is transmitted. For MPCPDUs originating at the OLT end, this can be the address any of the individual MACs. These MACs may all share a single unicast address, as explained in 77.1.2.

- **So at the OLT numerous MACs can have the same address**

- **In OLT**
  - MAC1, MAC2, … MACn can have the same address yet different LLIDs
- **Why can't we do that in the bonded ONU also?**
  - 1 MAC per Lane, with the same address
  - 1 LLID per Lane
  - Can then grant per Lane allowing easy mixing & matching of bonded and non-bonded ONUs on the same ODN



New stuff

Conclusions

- Bonding at RS can allow mixing and matching ONUs with various bonding configurations for both upstream and downstream.
- Granting lanes independently is feasible
- Granting lanes independently makes more efficient use of the PON than granting all bonded lanes of an ONU together

Thank you

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Additional examples of filling

ONU Models

Model	Description
100	Lane A, non-bonded
101	Lane B, non-bonded
102	Lane C, non-bonded
103	Lane D, non-bonded
201	Lanes A & B bonded
202	Lanes C & D bonded
400	4 bonded lanes

Models per Example

ONU	Ex 5	Ex 6	Ex 7	Ex 8	Ex 9	Ex 10	Ex 11	Ex 12
ONU 1	400	400	202	201	201	400	400	400
ONU 2	202	202	202	102	201	202	202	201
ONU 3	202	201	202	102	201	202	202	202
ONU 4	100	100	100	100	100	100	100	102
ONU 5	100	100	100	100	100	100	100	103
ONU 6	101	101	100	101	101	100	101	100
ONU 7	101	101	100	101	101	100	101	101
ONU 8	101	101	100	101	101	100	101	102
Models	4	4	2	4	3	3	4	7

Example 5			
Land A	Lane B	Lane C	Lane D
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
4	6	2	2
4	6	2	2
5	7	2	2
5	8	2	2
-	-	3	3
-	-	3	3

Example 6			
Land A	Lane B	Lane C	Lane D
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
3	3	2	2
3	3	2	2
4	6	2	2
4	6	2	2
5	7	-	-
5	8	-	-

Example 7			
Land A	Lane B	Lane C	Lane D
4		1	1
4		1	1
5		1	1
5		1	1
6		1	1
6		1	1
7		1	1
8		2	2
-		2	2
-		2	2
-		2	2
-		3	3
-		3	3

Example 8			
Land A	Lane B	Lane C	Lane D
4	6	2	
4	6	2	
5	7	2	
5	8	2	
1	1	2	
1	1	2	
1	1	2	
1	1	3	
1	1	3	
1	1	3	
1	1	-	

	Capacity	
ONU	Grntd	Rqst
1	16	13
2	8	7
3	4	3
4	2	2
5	2	2
6	2	2
7	1	1
8	1	1
Unts Grntd	36	31
Total Capacity		40
Unused Capacity		9
Efficiency		**77.5%**
Statistical Gain		**Poor**

	Capacity	
ONU	Grntd	Rqst
1	16	13
2	8	7
3	4	3
4	2	2
5	2	2
6	2	2
7	1	1
8	1	1
Unts Grntd	36	31
Total Capacity		40
Unused Capacity		9
Efficiency		**77.5%**
Statistical Gain		**Poor**

	Capacity	
ONU	Grntd	Rqst
1	14	13
2	8	7
3	4	3
4	2	2
5	2	2
6	2	2
7	1	1
8	1	1
Unts Grntd	34	31
Total Capacity		39
Unused Capacity		8
Efficiency		**79.5%**
Statistical Gain		**Fair**

	Capacity	
ONU	Grntd	Rqst
1	14	13
2	7	7
3	3	3
4	2	2
5	2	2
6	2	2
7	1	1
8	1	1
Unts Grntd	32	31
Total Capacity		33
Unused Capacity		2
Efficiency		**93.9%**
Statistical Gain		**Poor**

Example 4			
Land A	Lane B	Lane C	Lane D
1	1		
1	1		
1	1		
1	1		
1	1		
1	1		
1	2		
2	2		
4	2		
4	2		
5	2		
5	2		
6	-		
6	3		
7	3		
8	3		

Example 5			
Land A	Lane B	Lane C	Lane D
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
4	6	2	2
4	6	2	2
5	7	2	2
5	8	2	2
-	-	3	3
-	-	3	3

Example 6			
Land A	Lane B	Lane C	Lane D
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
3	3	2	2
3	3	2	2
4	6	2	2
4	6	2	2
5	7	-	-
5	8	-	-

Example 7			
Land A	Lane B	Lane C	Lane D
4		1	1
4		1	1
5		1	1
5		1	1
6		1	1
6		1	1
7		1	1
8		2	2
-		2	2
-		2	2
-		2	2
-		3	3
-		3	3

ONU	Capacity	
	Grntd	Rqst
1	13	13
2	7	7
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8	1	1
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Total Capacity		32
Unused Capacity		1
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Statistical Gain		**Good**

ONU	Capacity	
	Grntd	Rqst
1	16	13
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5	2	2
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