EPON over Coax

PHY Channel Bonding: Towards A Baseline Proposal

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Outline

- Requirements
- Focus initially on FDD downstream
  - Subsequently address TDD downstream & upstream
- Describe behavior of new sublayers and interfaces
  - Channel Bonding Interface (CBI)
  - Channel Bonding Sublayer (CBS)
    - Unicast Frames
    - Broadcast/Multicast Frames
  - Channel Combining Interface (CCI)
  - Channel Combining Sublayer (CCS)
- Configuration Information (Content, not yet format)
- Conclusions
- References
- Annex – Timing Illustrations

Channel Bonding Requirements

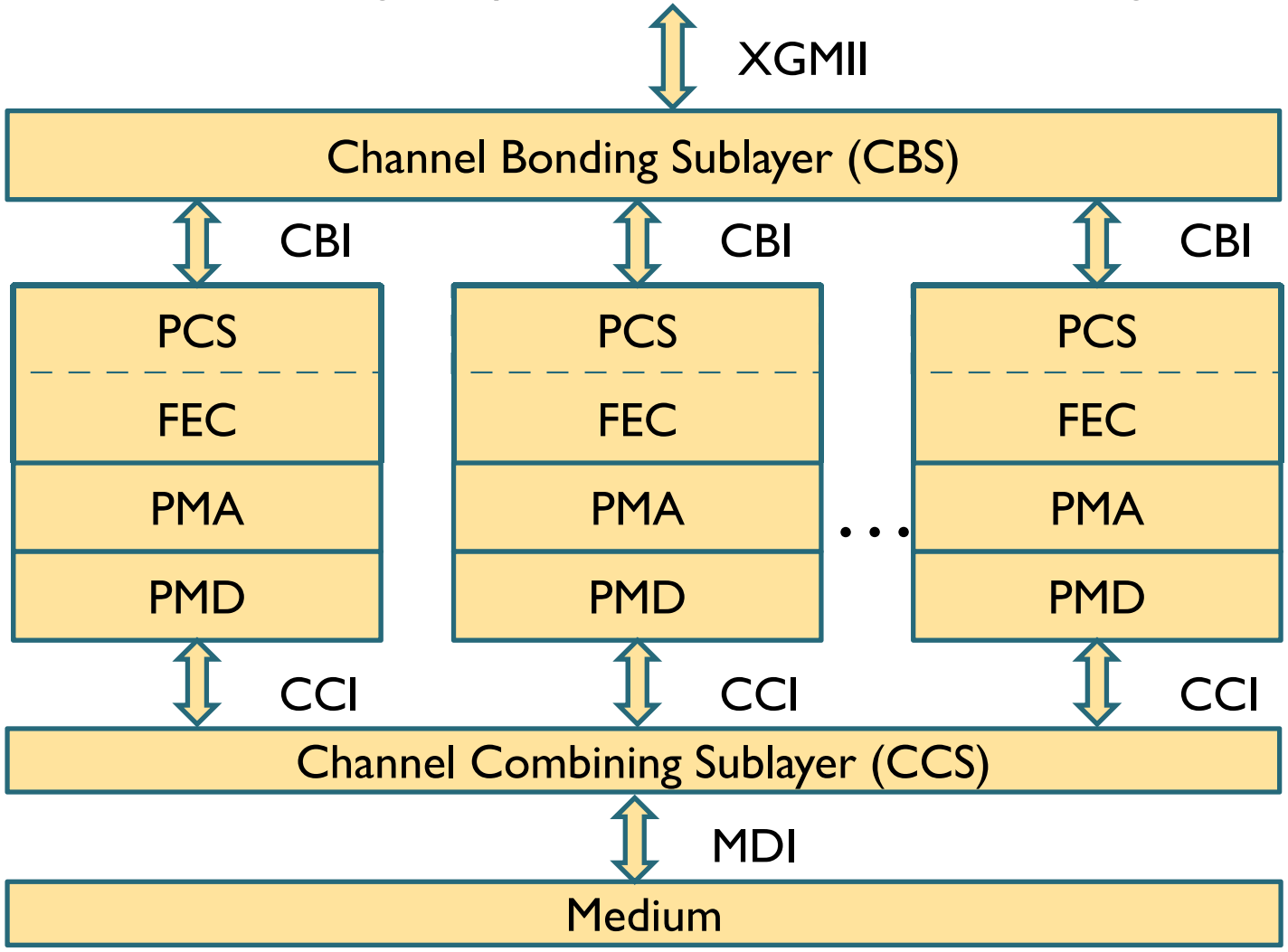
- FDD
  - Support CNUs with the same or fewer number of downstream channels than the CLT
  - No need to address channel bonding in upstream
- TDD
  - Support CNUs with the same or fewer number of channels than the CLT
- General
  - The jitter from the transmit XGMII interface to the receive XGMII interface needs to be zero or very small (several TQ)
  - Support unicast, multicast and broadcast frames
  - Support different bandwidths (due to exclusion sub-bands) on different channels

Requirements on other Sublayers

- The scheduler shall not schedule beyond the capacity of the bonded channels
- The jitter from the transmitter PCS to the receiver PCS is zero or small

Channel Bonding Sublayer

- Add Channel Bonding Sublayer (CBS) above the PCS
- Add Channel Bonding Interface between CBS and PCS
- Support multiple PCS/FEC/PMA/PMD sub-layers for multiple OFDM channels
- Add Channel Combining Sublayer below the PMD connected though CCI



Channel Bonding Interface (CBI)

- The Channel Bonding Interface is functionally identical to the XGMII interface

For Reference: XGMII interface

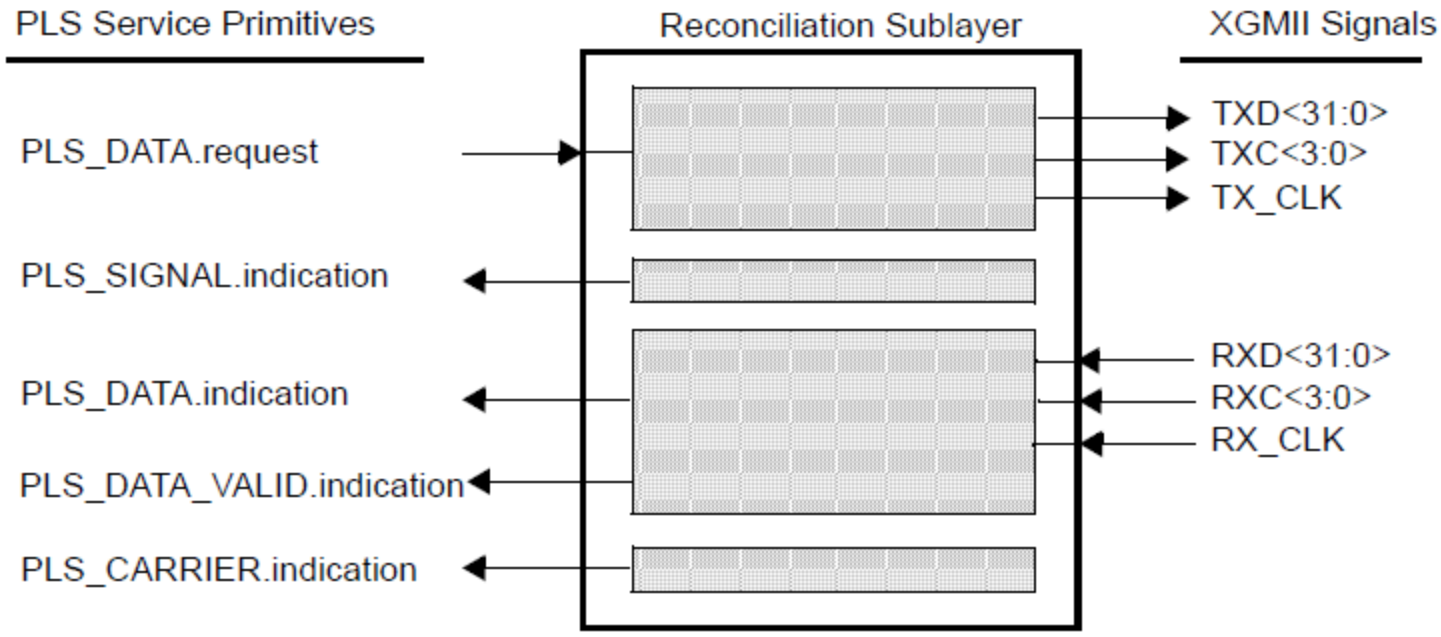
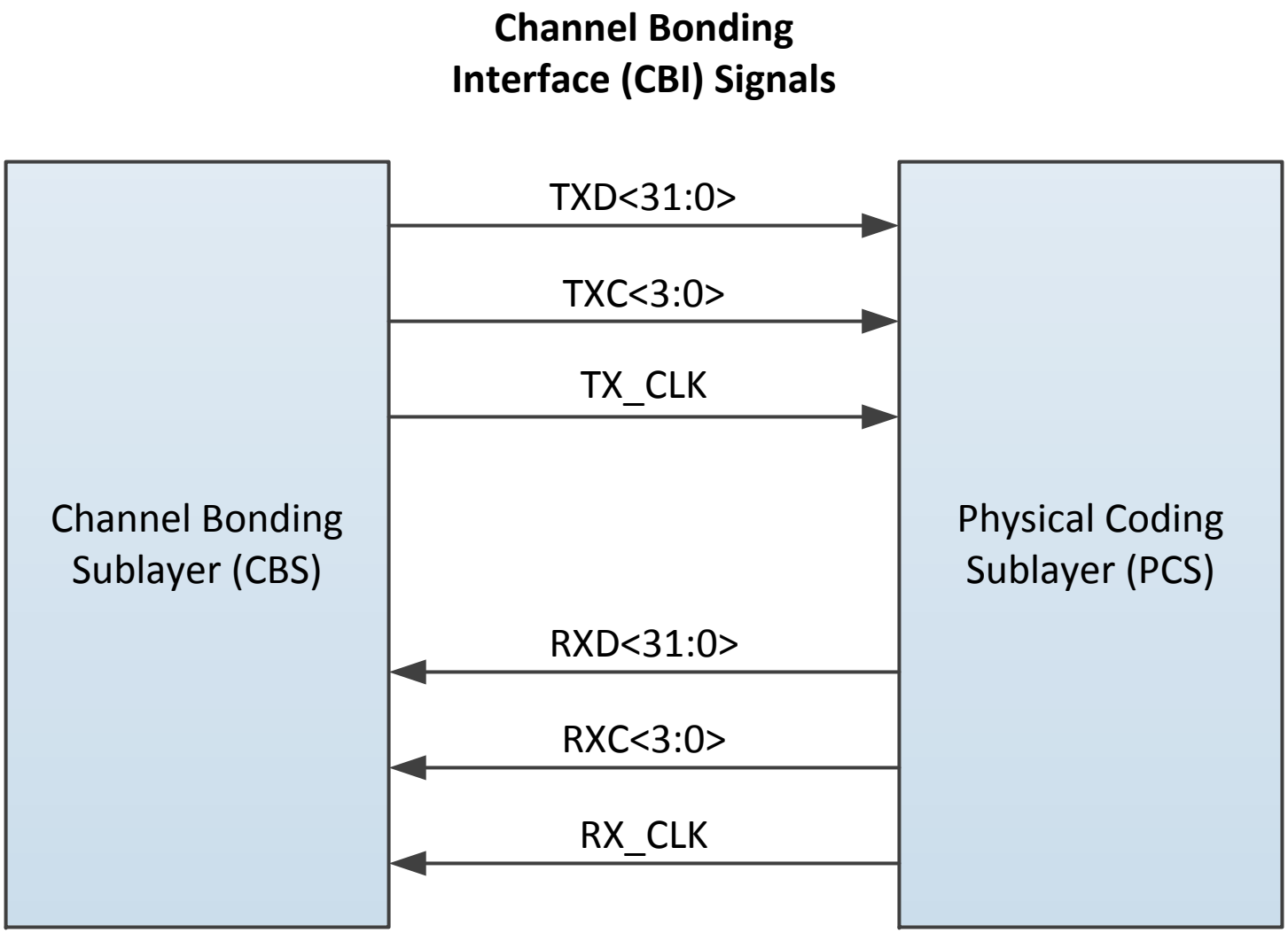


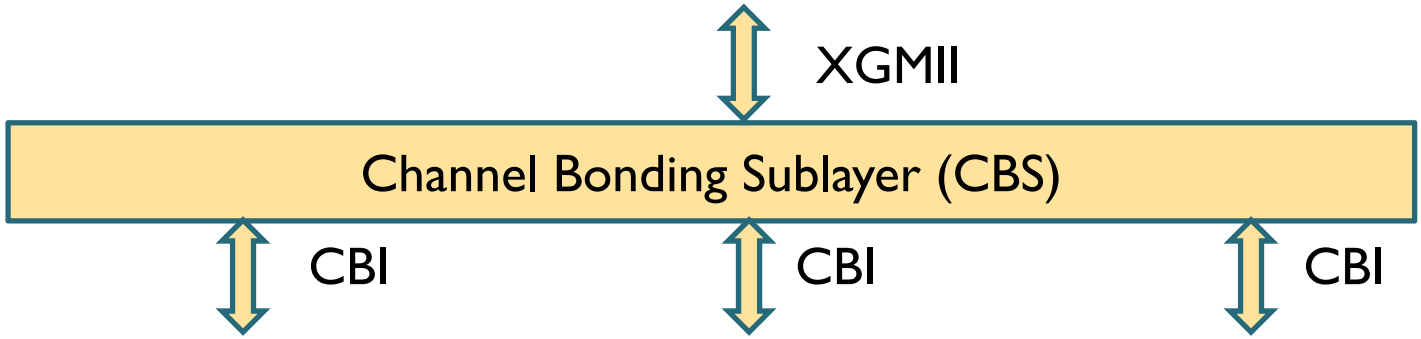
Figure 46–2—Reconciliation Sublayer (RS) inputs and outputs

Channel Bonding Interface (CBI)



Channel Bonding Sublayer (Transmit)

- On the Transmit side the CBS connects to the XGMII interface on the top and several CBI interfaces on the bottom



Channel Bonding Sublayer (Transmit)

- Inside the channel bonding sublayer there is a channel bonding table (CBT)
- The table is configured through the MDIO interface
- The table maps LLIDs to channel bonding interfaces
- For each LLID the table specifies which CBIs through which the LLID can reach its CNU

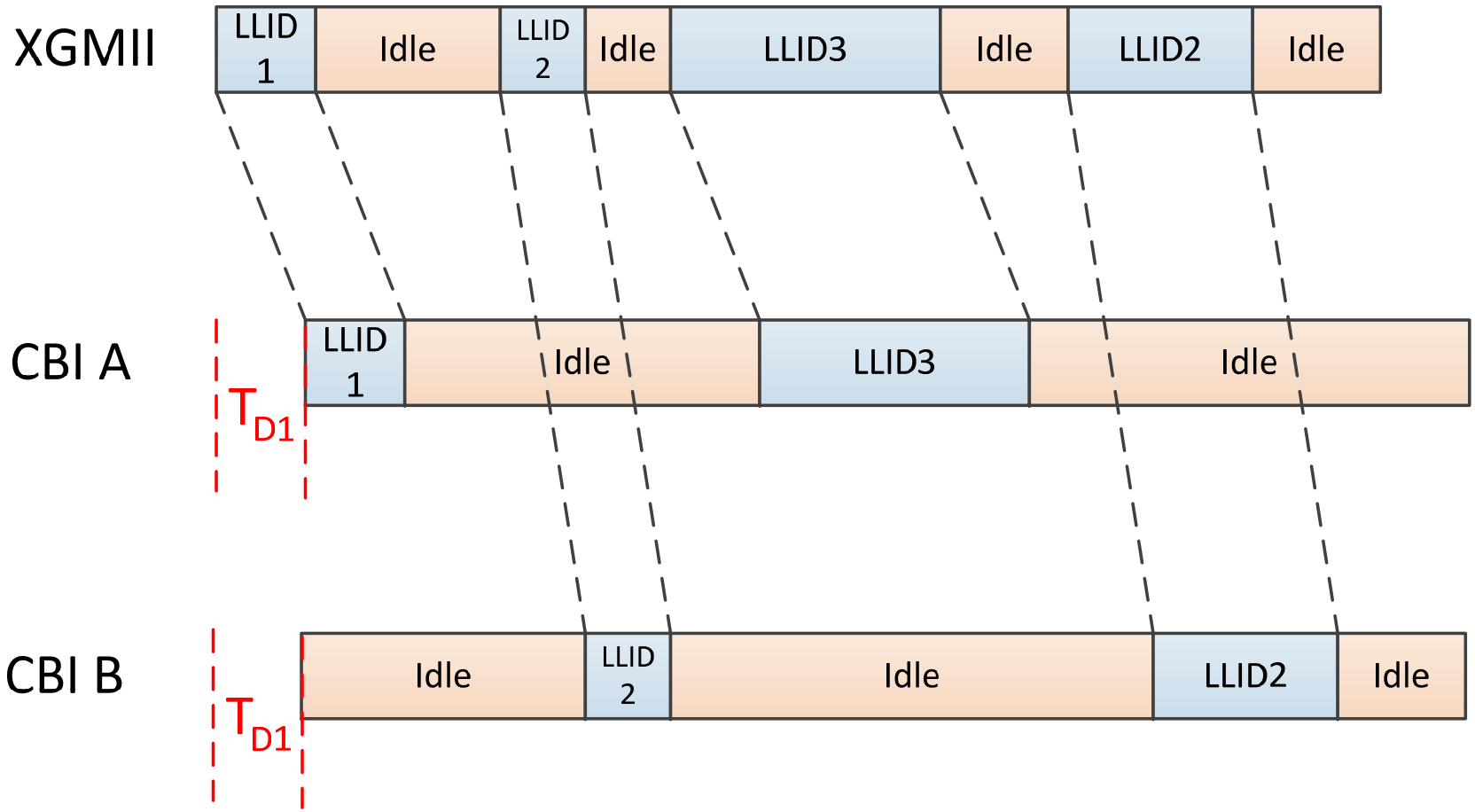
Example Channel Bonding Table

LLID	CBIs
5	1
7	1, 2
12	2

Channel Bonding Sublayer (Transmit)

- There is a fixed delay through the CBS
- The CBS parses the XGMII signal
- Ethernet Frames are sent to one of the CBIs in the channel bonding table
- On the CBI if there is not an Ethernet Frame the CBS sends Idles

CBS Transmit Illustration

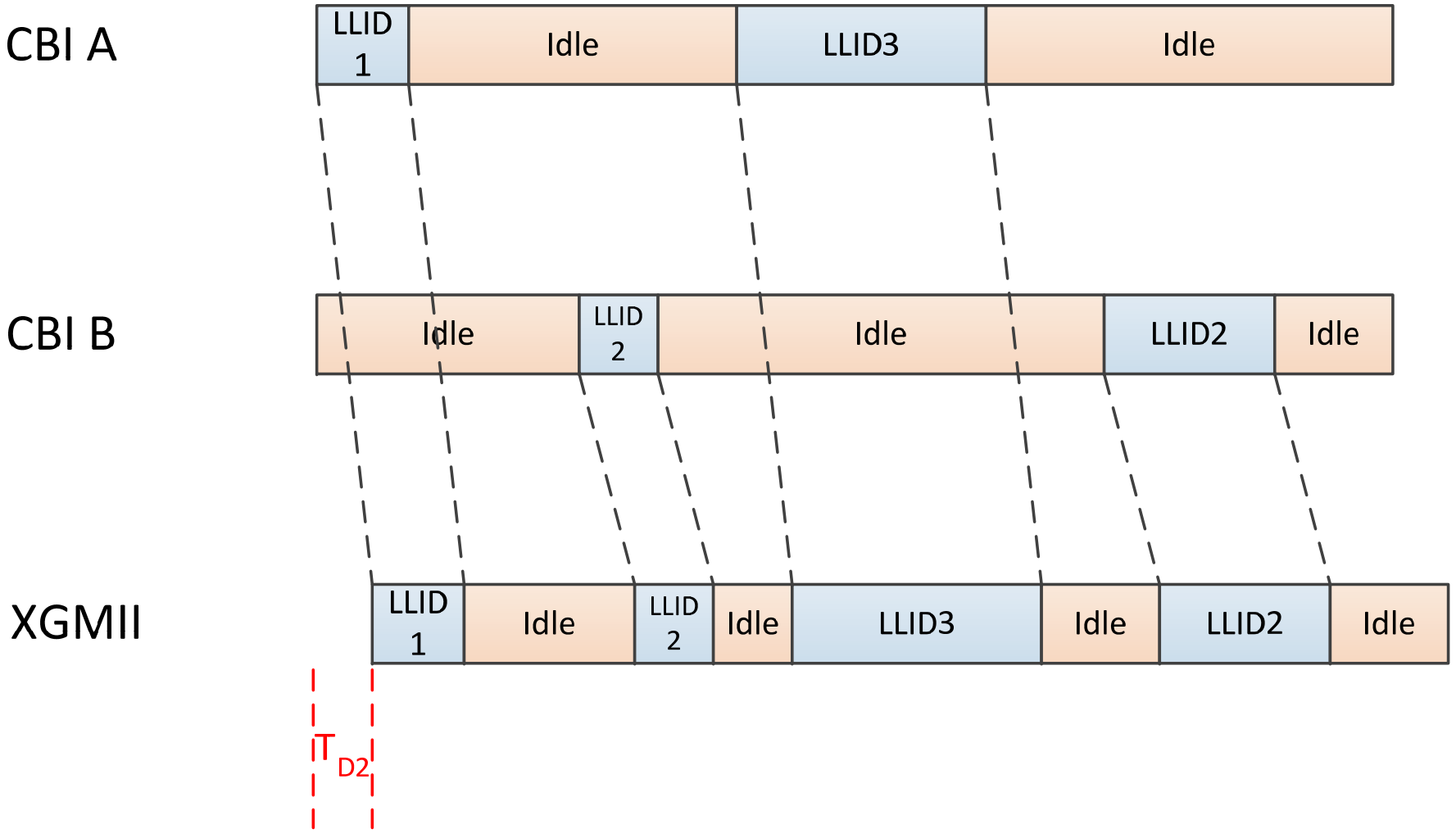


- Notice the fixed delay through the CBS

Channel Bonding Sublayer (Receive)

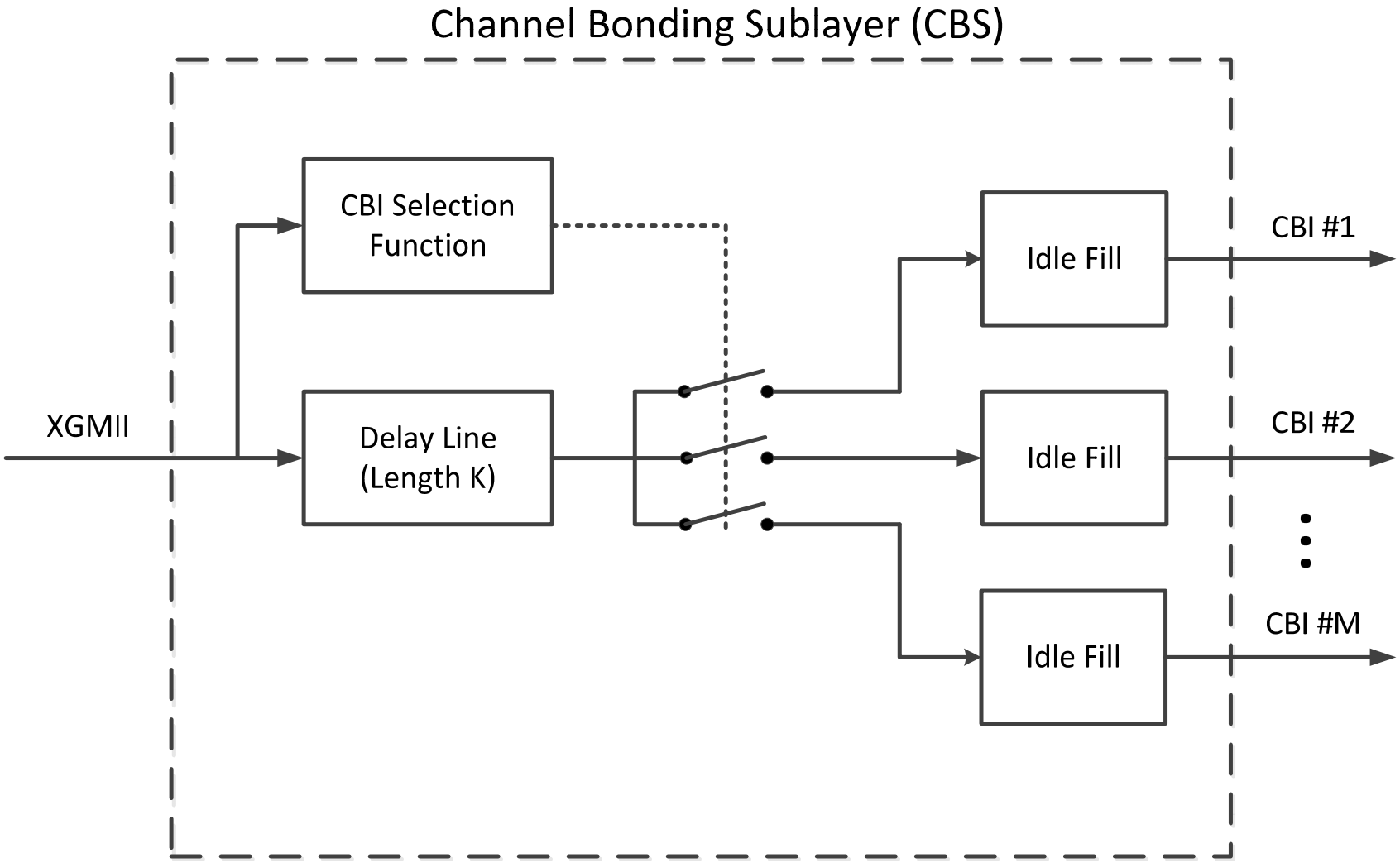
- There is a fixed delay through the CBS
- The CBS parses the CBI signals
- If there is an Ethernet Frame on one of the CBIs then that Ethernet Frame is sent up the XGMII
- On the XGMII if there is not an Ethernet Frame the CBS sends Idles

CBS Receive Illustration



- Notice the fixed delay through the CBS

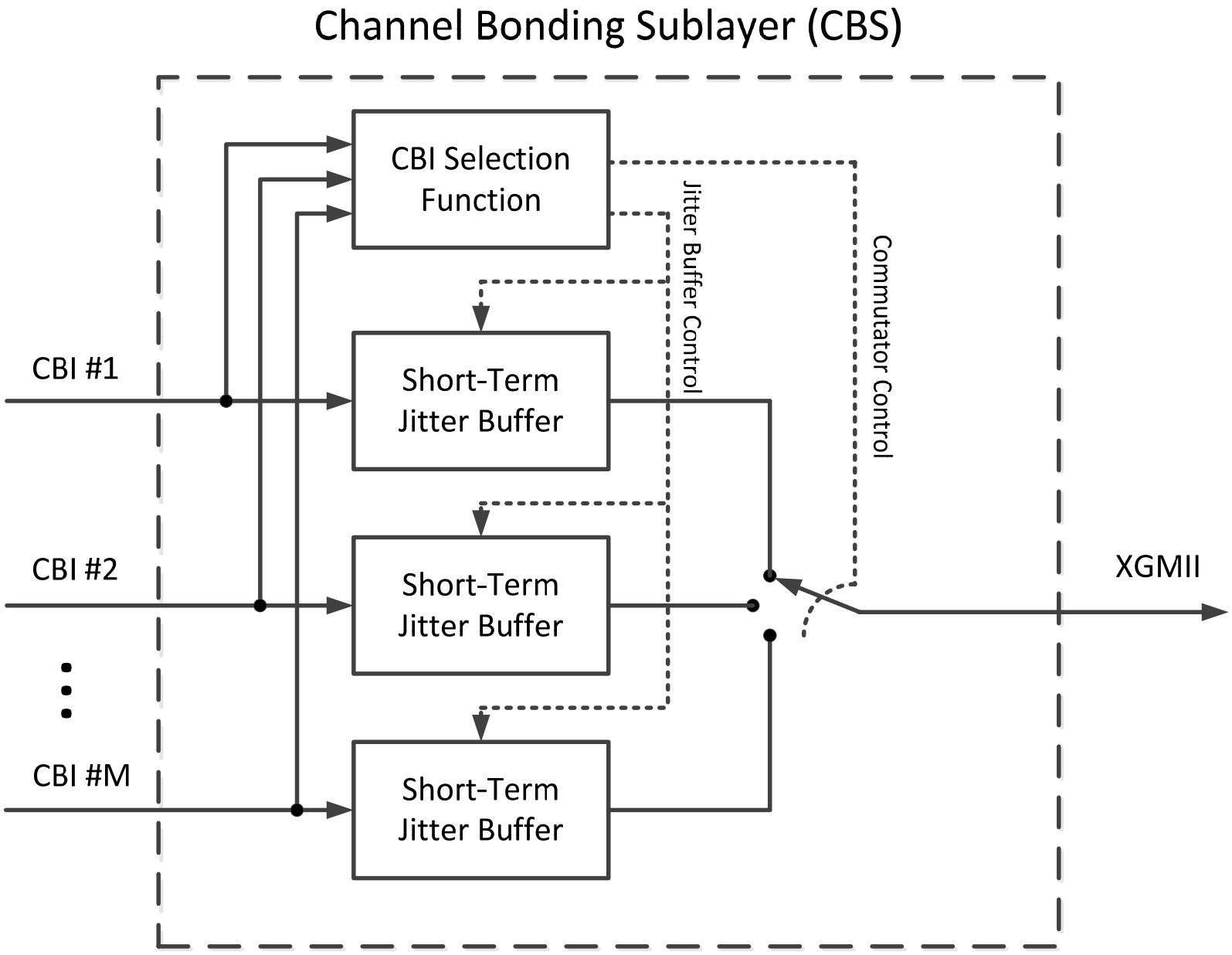
CBS TX Block Diagram (in CLT)



CBS TX Block Diagram Description

- Delay Line
  - Width matches XGMII data width (32 bits)
  - Length K is implementation parameter
- CBI Selection Function
  - Parses the XGMII stream and selects the CBI based on the LLID
  - After delay of K clocks the commutator is connected to the appropriate CBI, based on CBI Table
  - The commutator stays that position until changed by a new LLID
- Idle Fill
  - If it receives an input from the commutator it transmits that to the CBI, otherwise if fills with an Idle

CBS Receive Block Diagram (in CNU)



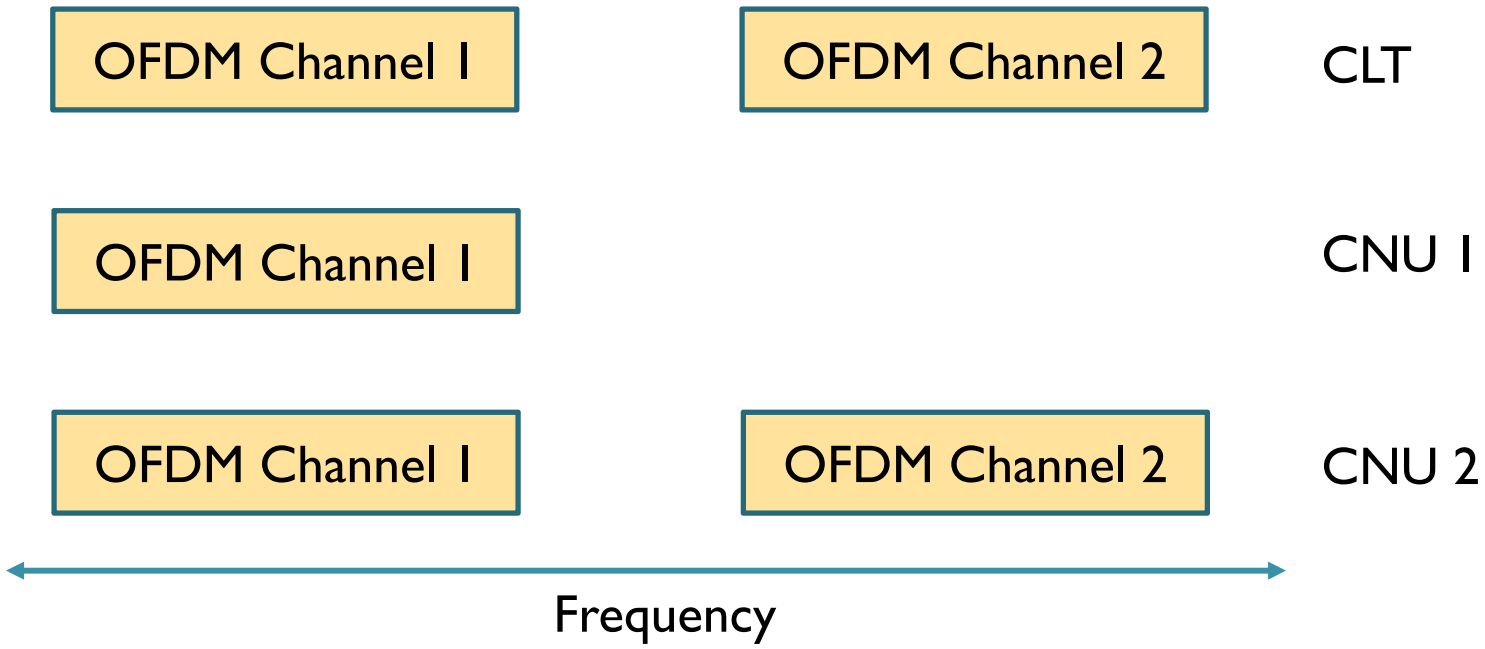
CBS RX Block Diagram Description

- Short-Term Jitter Buffer
  - If we could guarantee exactly the same delay through each channel this would just be a short delay line, and there would never be a frame overlap between any of the CBIs
  - In case there is a small jitter over each PHY channel, the jitter buffer is used to make sure there is no frame overlap
- CBI Selection Function
  - Controls Jitter Buffers to make sure there is no frame overlap coming out of the jitter buffers
  - Controls commutator to select the channel with the current frame
  - Stays on that channel until there is a frame on another channel

Broadcast/Multicast Frames

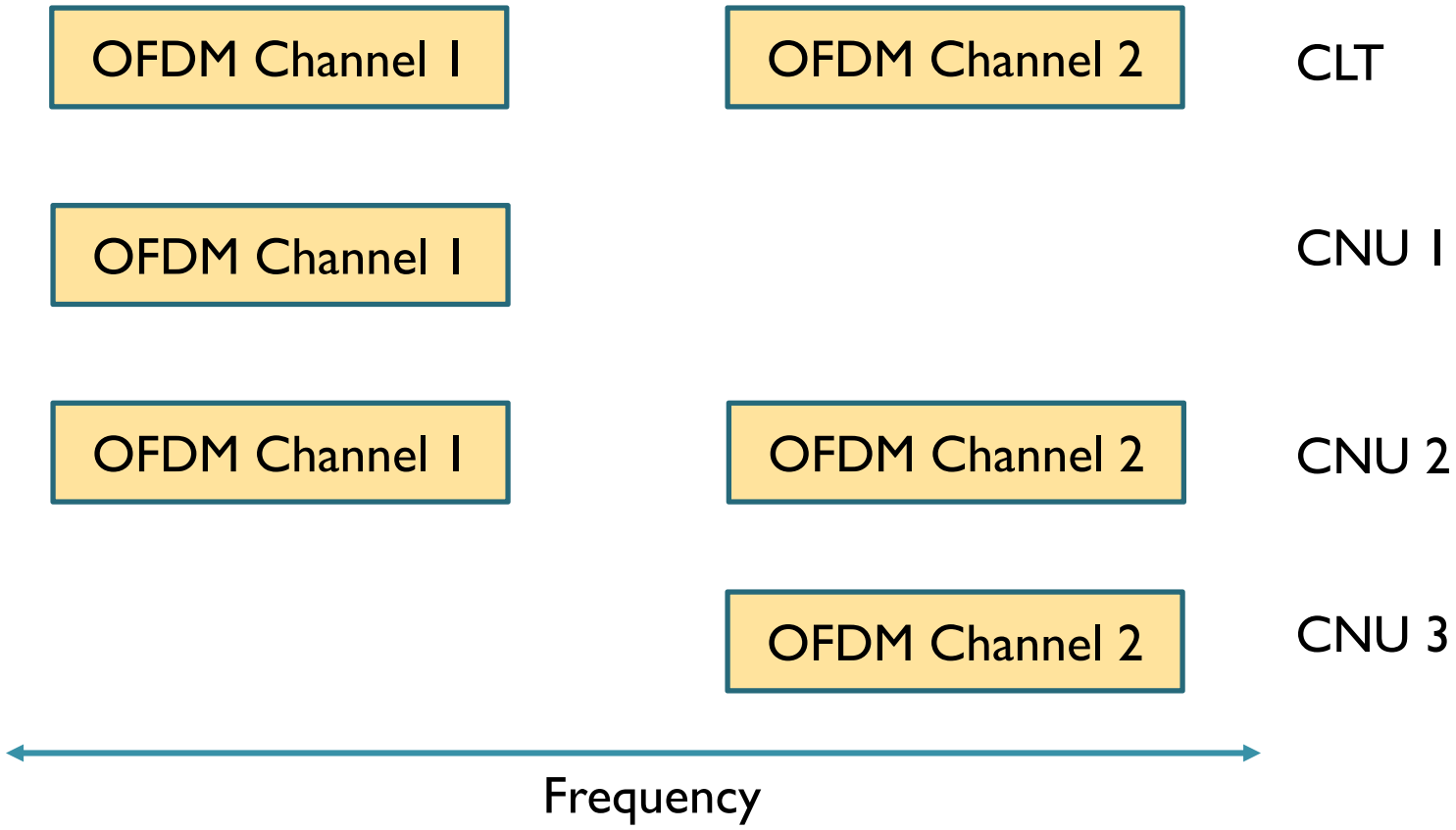
- To maximize throughput we want to send broadcast/multicast frames on as few channels as needed to reach the broadcast/multicast group
- For each broadcast/multicast LLID we define the broadcast channel group to reach the broadcast/multicast group (BCG)
- In many cases this group of channels is a single channel in the BCG
- In some cases more than one channel is required to reach all the CNUs in the broadcast/multicast group
- A few examples are given on the next few slides

Broadcast/Multicast Example #1



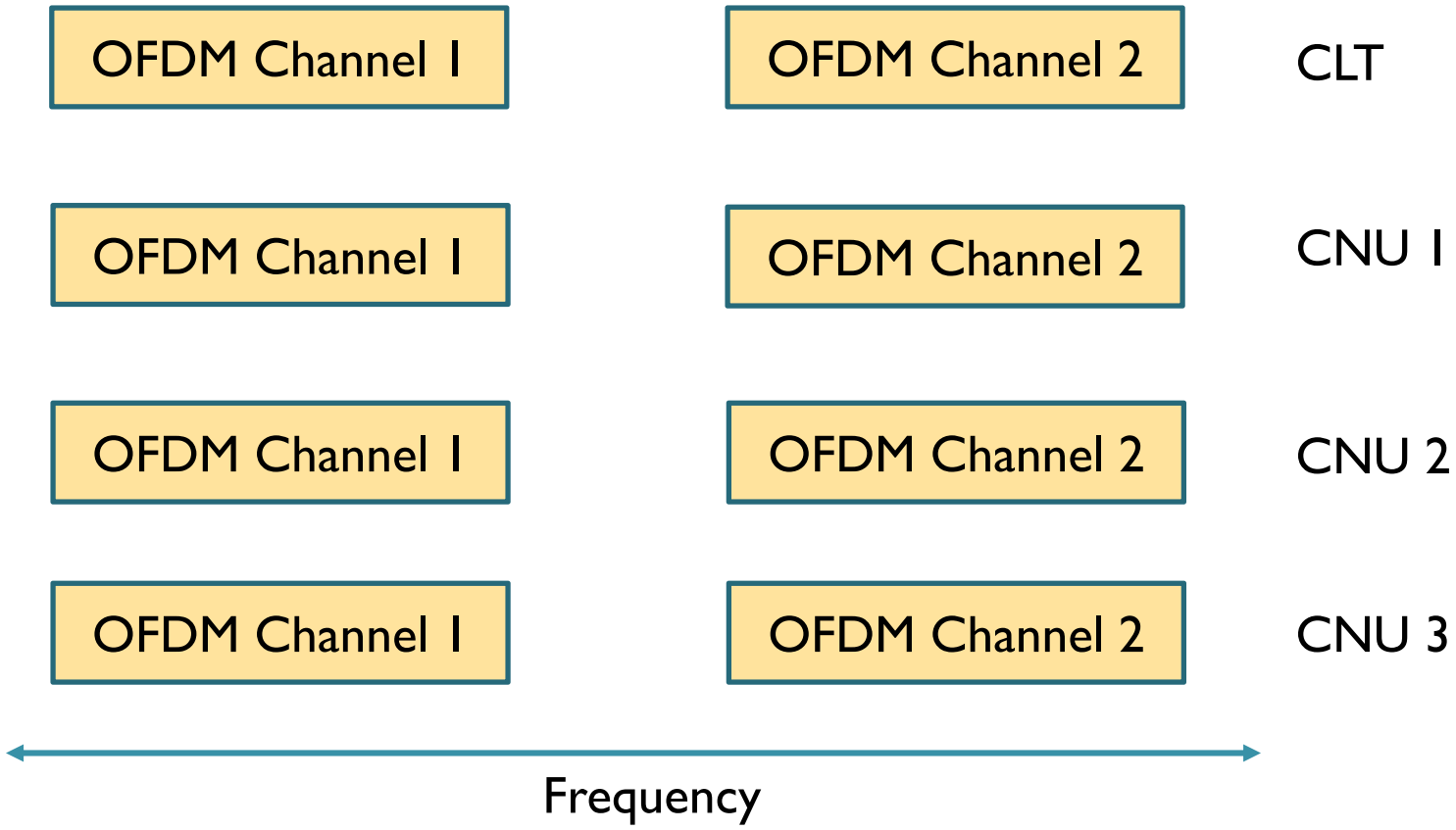
- If we send the broadcast/multicast frames on Channel 1 it will be received by both CNUs
  - BCG = {1}

Broadcast/Multicast Example #2



- In this case the broadcast/multicast frames must be sent on both Channel 1 and Channel 2 to be received by all CNUs
  - BCG = {1,2}

Broadcast/Multicast Example #3



- Broadcast/multicast frames can be sent on either Channel 1 or Channel 2 and be received by all CNUs. So there are two possible BCGs
  - BCG = {1} or {2}

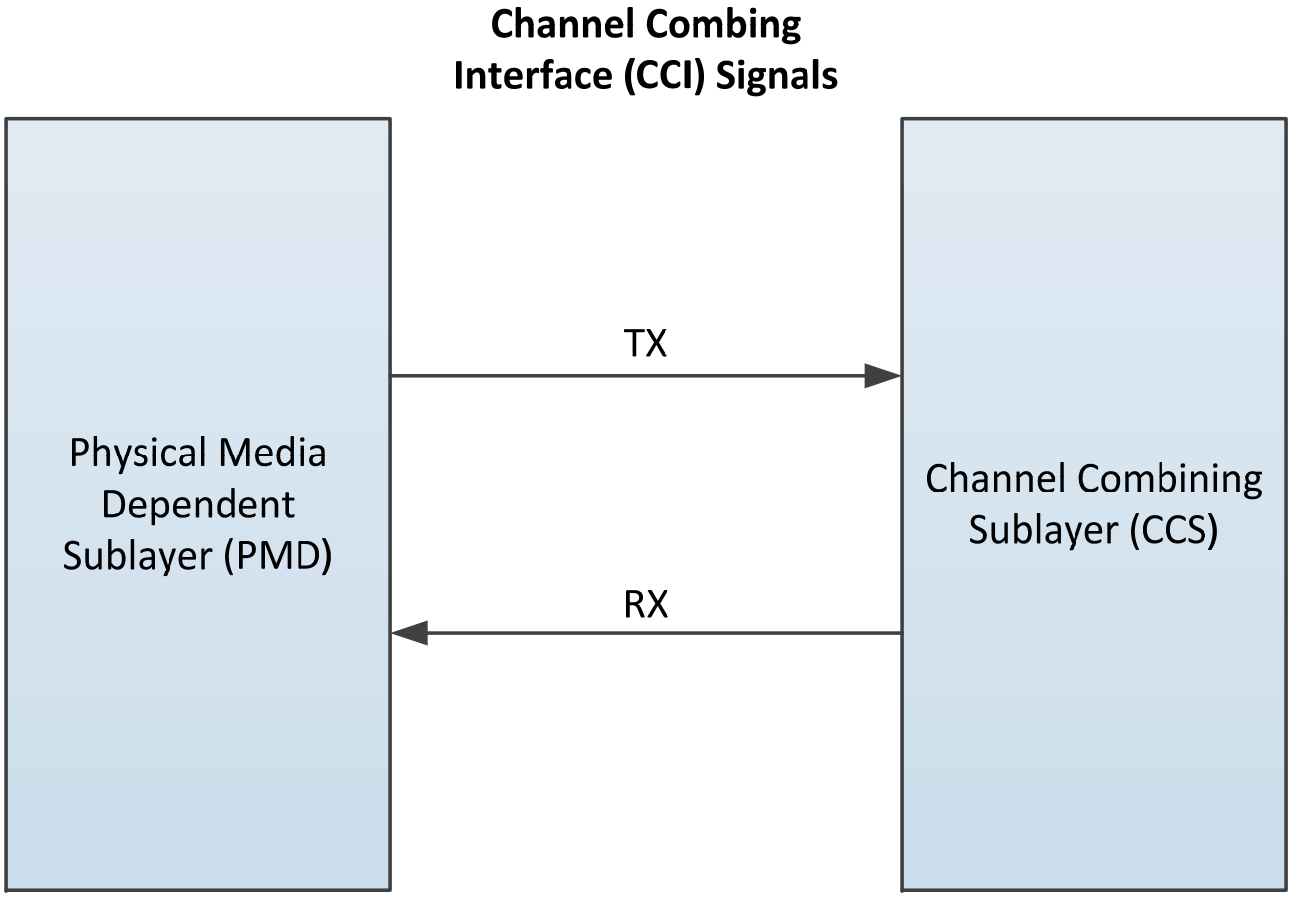
Channel Bonding Sublayer

Broadcast/Multicast Frames

- Transmit
  - The CBS is configured with a broadcast channel group (BCG) for the LLID
  - The CBS transmits the broadcast/multicast frame on all the channels in the BCG
- Receive
  - In the cases where it is possible for a CNU to receive multiple copies of the broadcast/multicast frames the CNU is configured with a primary broadcast/multicast channel number for the LLID
  - The CBS only send up to the XGMII broadcast/multicast frames received on the primary broadcast/multicast channel

Channel Combining Interface (CCI)

- RF Interface for transmit and receive



Channel Combining Sublayer (CCS)

- Transmit
  - Combine multiple RF signals from all the PMDs into a single RF signal
- Receive
  - Distribute the RF signal to all PMDs

Configuration Information (Not Format)

- A list of what can be configured in the channel bonding and the channel combining sublayers through MDIO

Parameter	Description
NumChan	Number of OFDM Channels
ChannelBondingTable	A Table with channel bonding interface list for each LLID For broadcast/multicast channels the channel bonding list is the broadcast/multicast channel group
Primary Broadcast/Multicast Channel	In the RX (CNU) if it is possible to receive more than one copy of a broadcast/multicast frames, any copies for that LLID are to be discarded

Channel Bonding Sublayer Configuration Information

Configuration Information (Not Format)

- A list of what can be configured in the channel bonding and the channel combining sublayers through MDIO

Parameter	Description
NumChan	Number of OFDM Channels

Channel Combing Sublayer Configuration Information

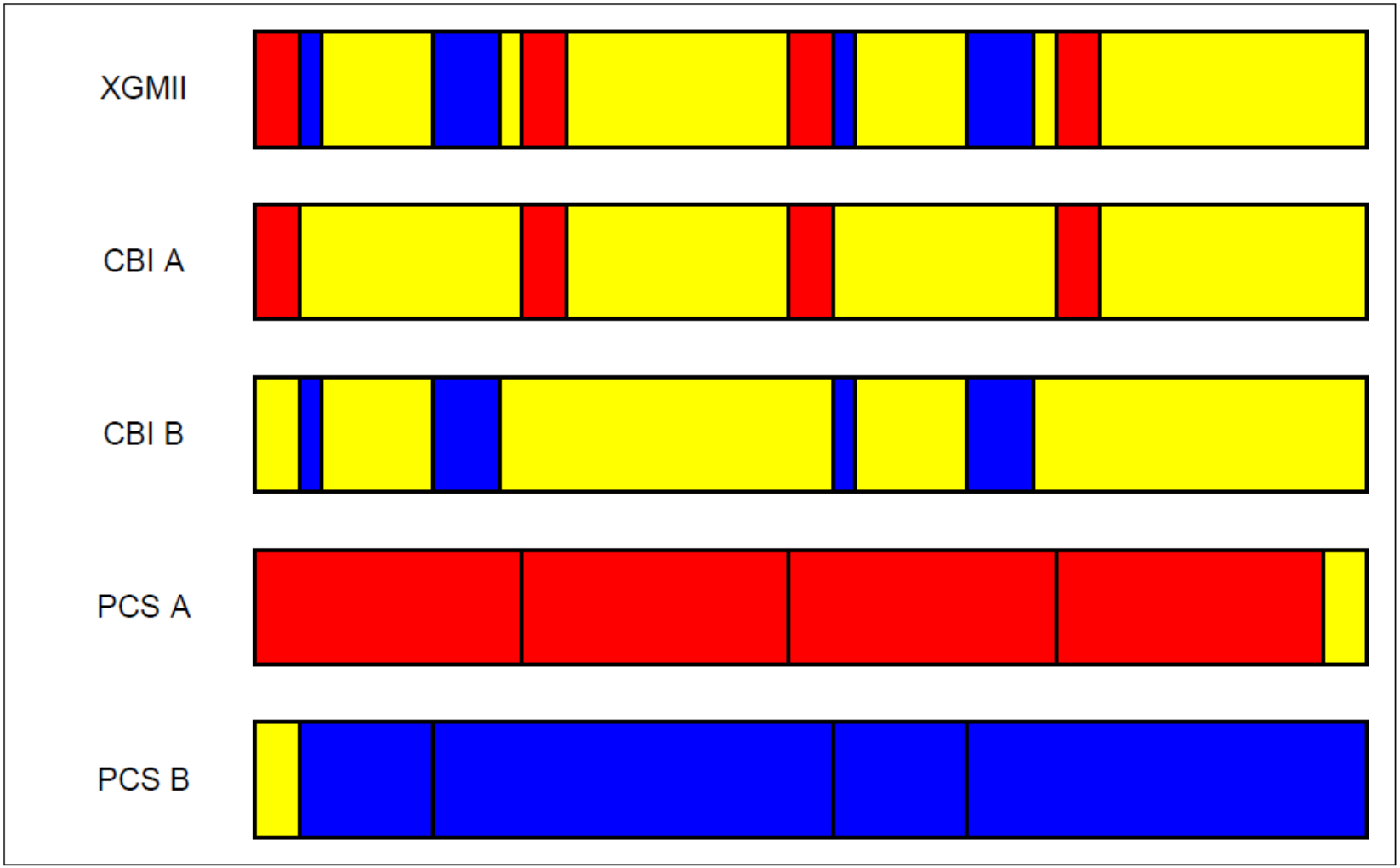
Conclusions

- A Baseline proposal for PHY-Layer Channel Bonding was provided
- Introduced new sublayers and interfaces
  - Channel Bonding Interface (CBI)
  - Channel Bonding Sublayer (CBS)
  - Channel Combining Interface (CCI)
  - Channel Combining Sublayer (CCS)
- Specified the CBI and CCI interfaces
- Specified the behavior of the CBS and CCS
- Provided timing illustrations for CBS on both transmit and receive demonstrating constant delay
- Provided example of how CBS handles broadcast/multicast Frames on both transmit and receive

Annex – Timing Illustrations

- Subsequent Illustration show timing at several sublayers
- Fixed delay through all the sublayers
- Idle insertion for FEC not shown
- For illustration purposes only, the delay is zero
- In practice, there will be a fixed non-zero delay
- Color Code
  - Red – Channel A Ethernet Frames
  - Blue – Channel B Ethernet Frames
  - Yellow – Idle Frames

Annex – Timing Illustrations



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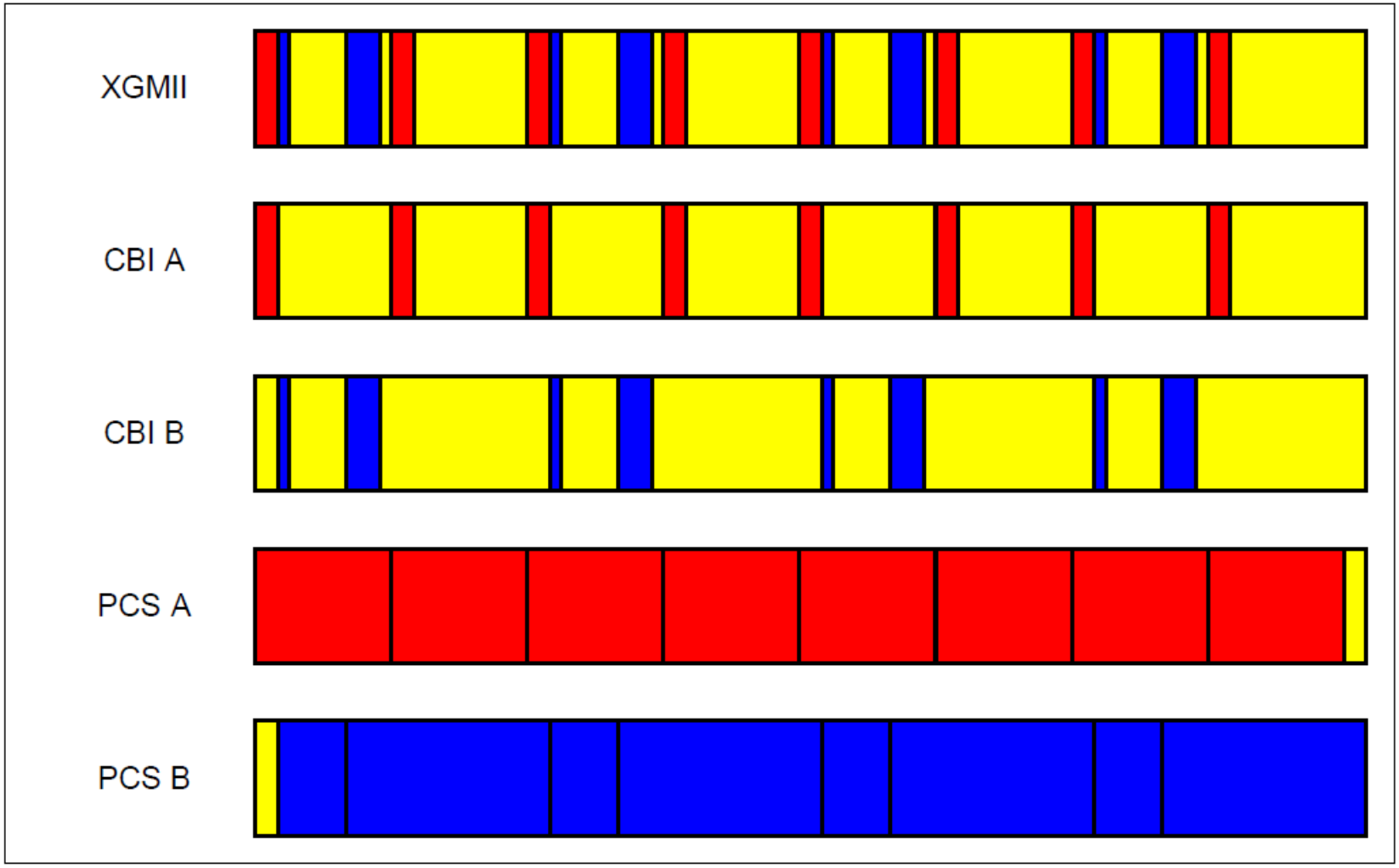

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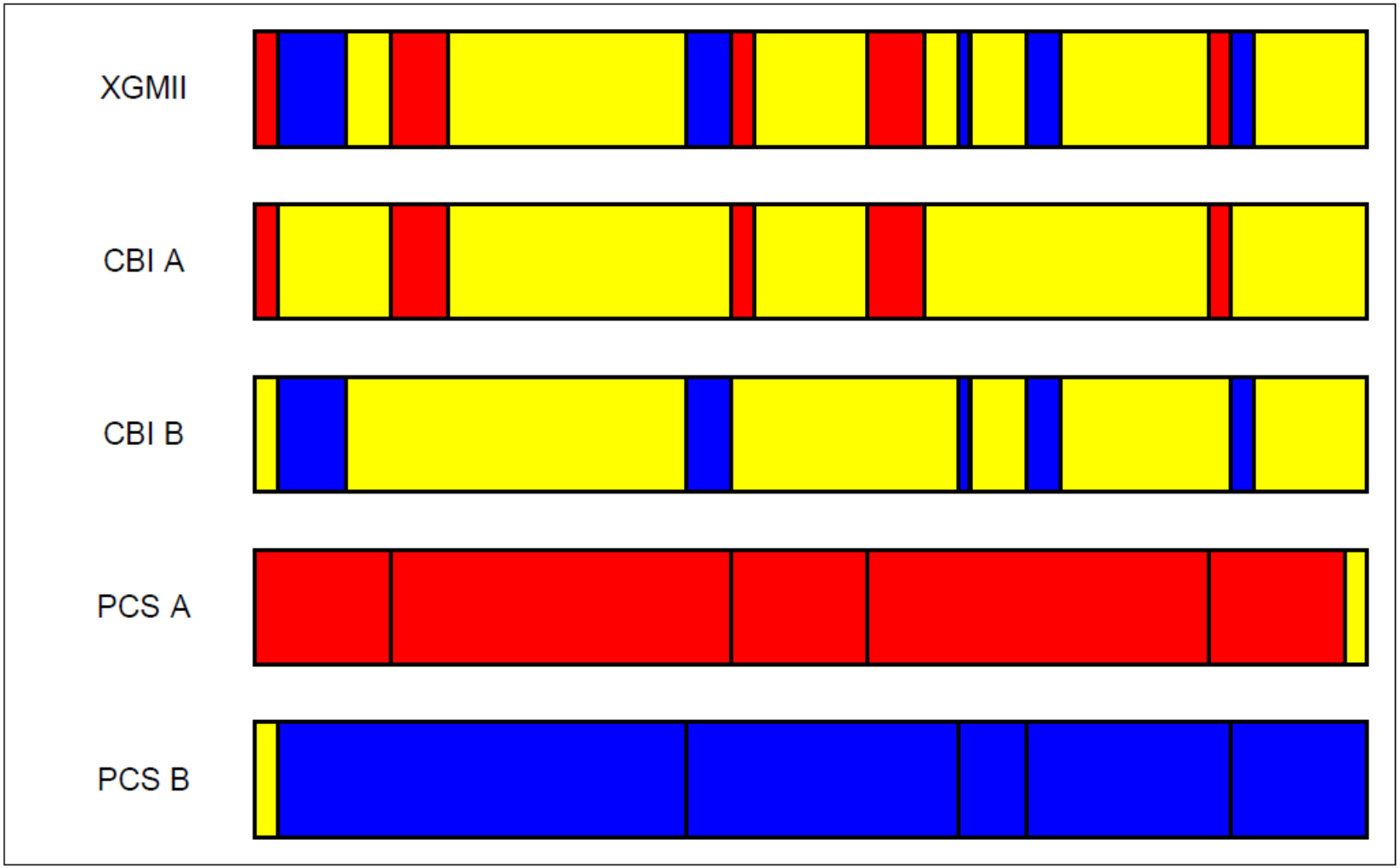

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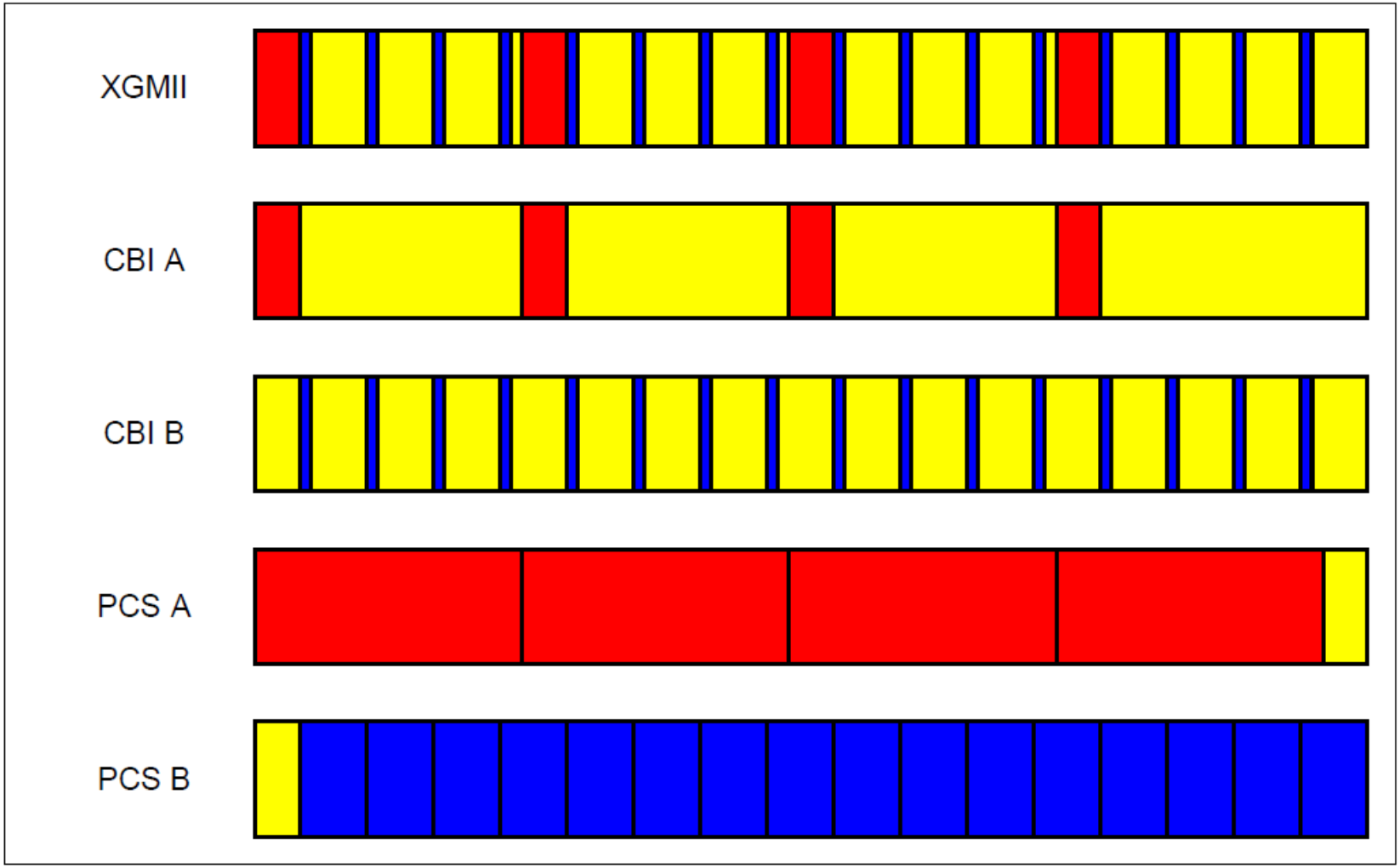
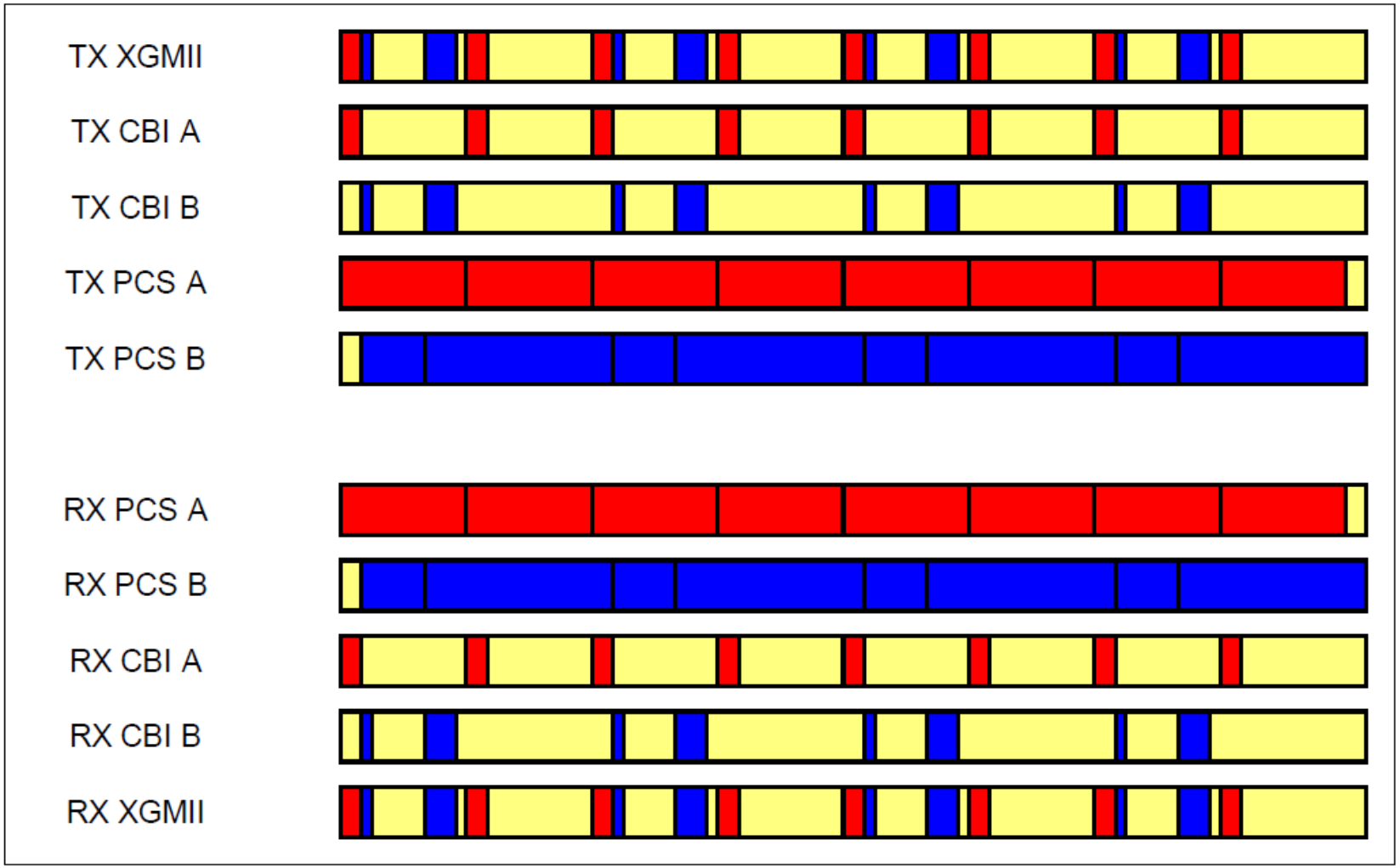


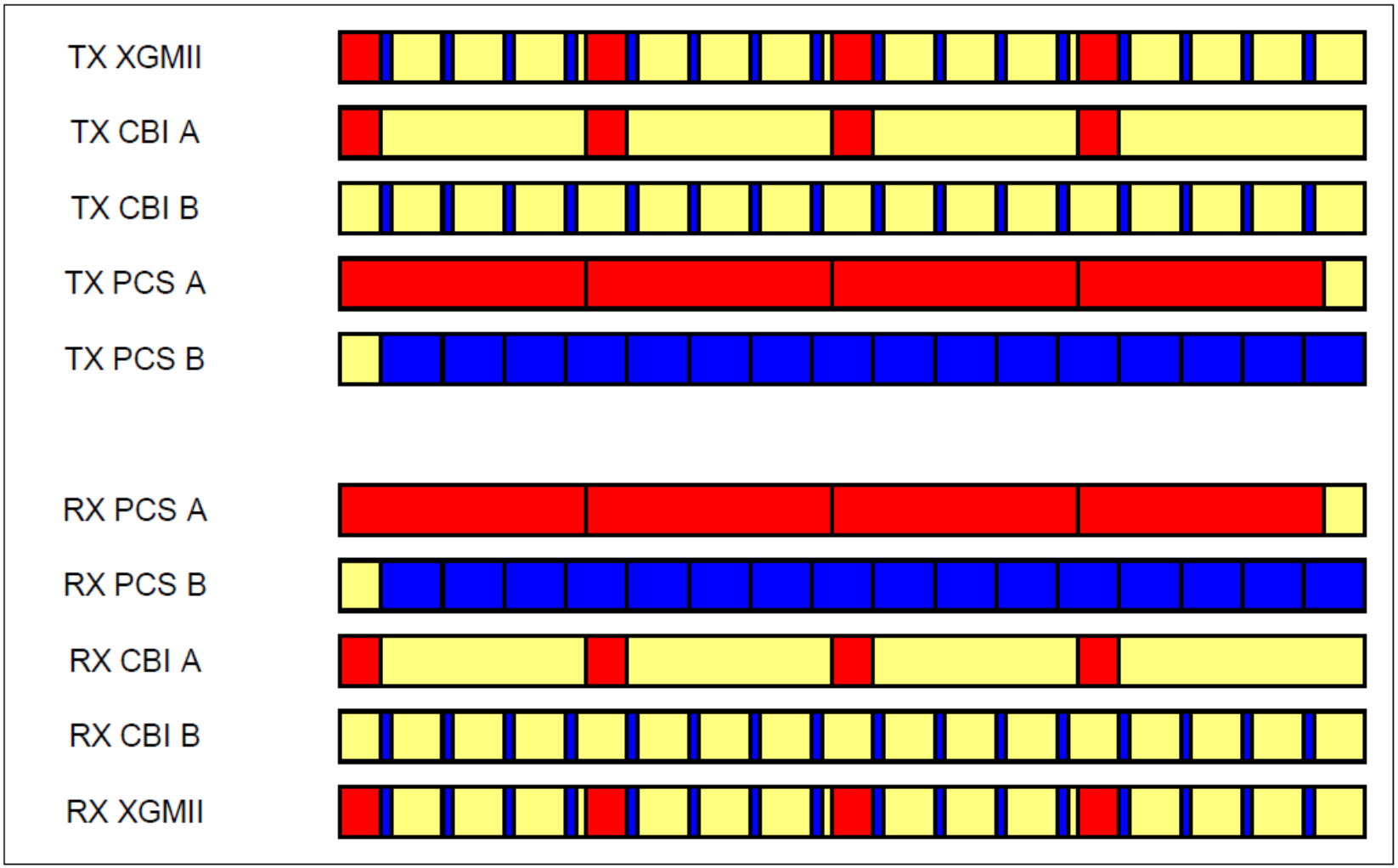
Additional Timing Illustrations

- Added PCS and CBS receive sublayers
- Still zero delay in each sublayer

Timing Illustration (TX and RX)



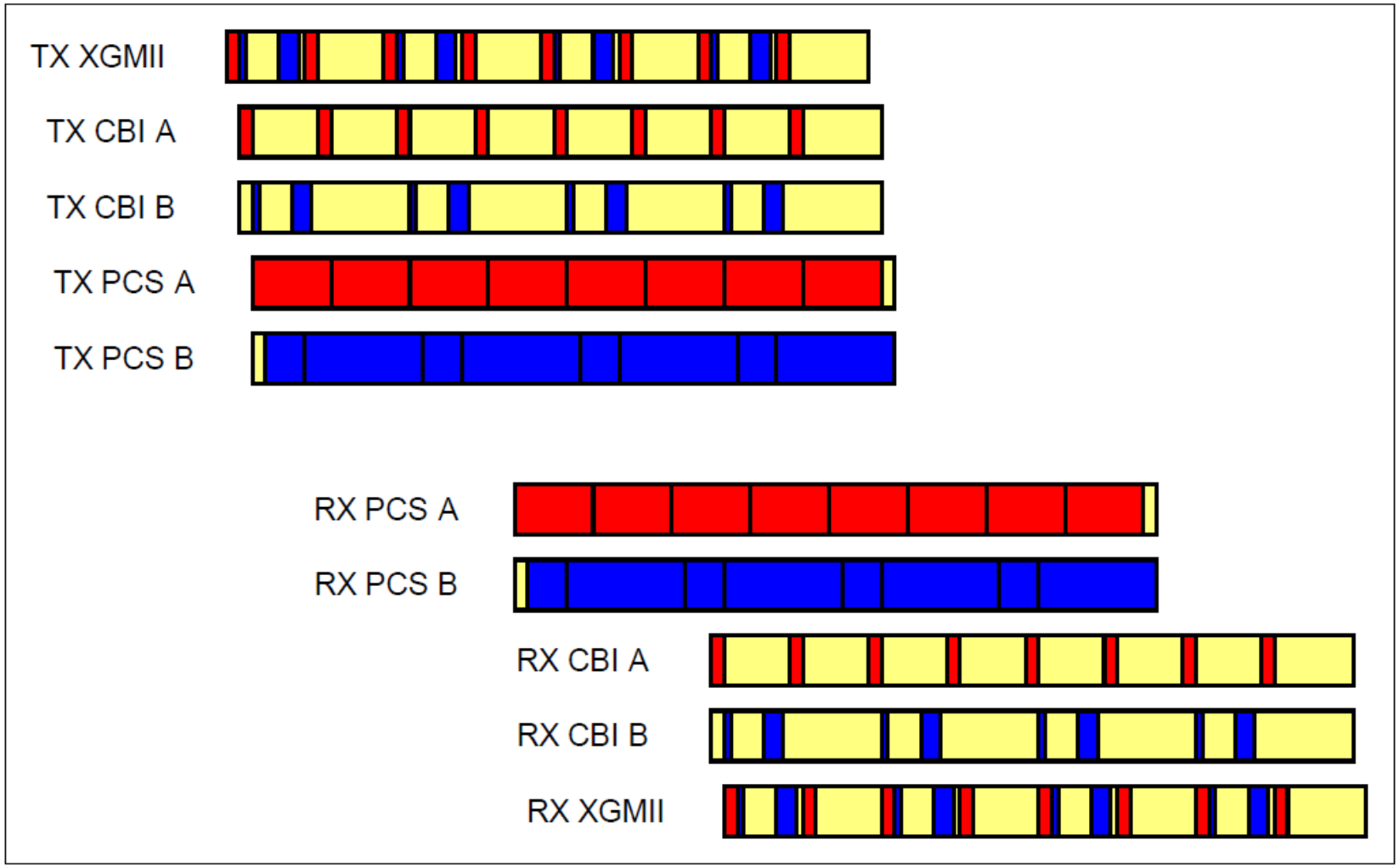
Timing Illustration (TX and RX)



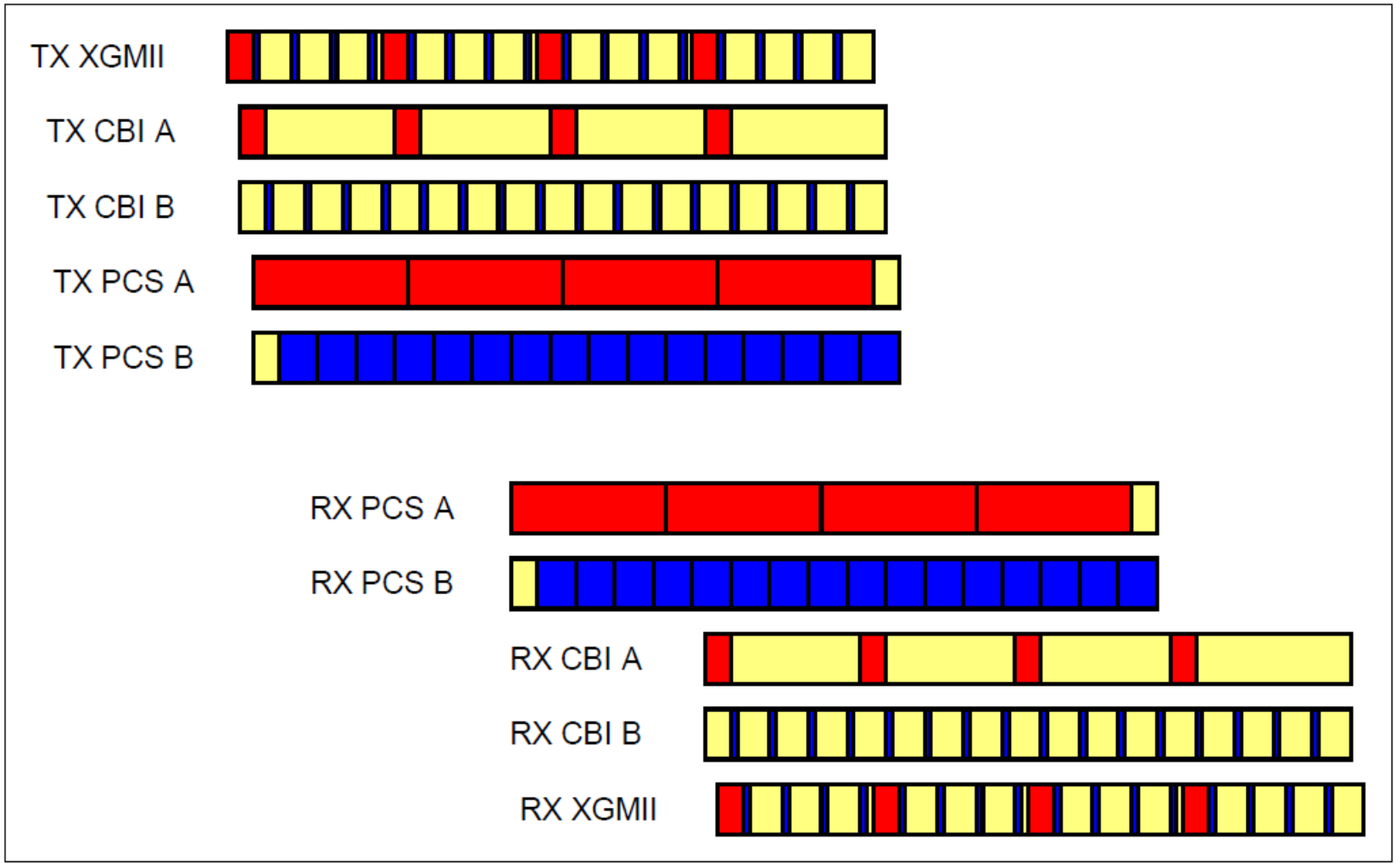
Additional Timing Illustrations

- Added PCS and CBS receive sublayers
- Show fixed non-zero delay in sublayers

Timing Illustration (TX and RX)



Timing Illustration (TX and RX)



References

1. Steve Shellhammer, Juan Montojo, Andrea Garavaglia, Patrick Stupar, Nicola Varanese and Christian Pietsch, "Channel Bonding Sublayer," shellhammer_03b_1112, November 2012