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Title: Support LTTPR Transparent
Applied to: USB4 Specification Version 1.0

Brief description of the functional changes:

Adds the explicit support for LTTPR Transparent mode and the transitions in and out of the different modes.
Change LTTPR mode to LTTPR Non-transparent.

Benefits as a result of the changes:

Provides a better solution for the current ecosystem which wishes to transition back and forth between the modes.

An assessment of the impact to the existing revision and systems that currently conform to the USB specification:

None

An analysis of the hardware implications:

None

An analysis of the software implications:

None

An analysis of the compliance testing implications:

None

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Actual Change

(a). Section 2.2.10.2 Display Tunneling

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A DP Protocol Adapter can either operate in LTTPR Non-transparent mode, LTTPR Transparent mode or Non-LTTPR mode. In LTTPR Non-transparent and LTTPR Transparent modes, the DP OUT Protocol Adapter and DP IN Protocol Adapter behave as a single LTTPR. In Non-LTTPR mode, the DP OUT Protocol Adapter and DP IN Protocol Adapter behave such that DPRX appears to be directly attached to DPTX.

Figure 2-20 shows the system in Figure 2-19 from a DisplayPort perspective when the DP IN and DP OUT Protocol Adapters are in LTTPR Non-transparent and LTTPR Transparent Modemodes. Figure 2-21 shows the system in Figure 2-19 from a DisplayPort perspective when the DP IN and DP OUT Protocol Adapters are in Non-LTTPR Mode.

Figure 2-20. DP IN and OUT Protocol Adapters in LTTPR Non-transparent and LTTPR Transparent Modes

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(b). Section 10.3.1 DisplayPort

10.3.1   DisplayPort

A DP Adapter shall support two three modes of operation:

- **LTTPR Non-transparent** – LT-tunable PHY Repeater – non-Transparent Mode(LTTPR).

- **LTTPR Transparent** – LT-tunable PHY Repeater – Transparent Mode.

- **Non-LTTPR** – Non-LT-tunable PHY Repeater (Non-LTTPR).

DisplayPort Link Training is executed over the tunnel in one of two ways:

- DPTX Managed, Sequential Link Training – In this mode the DPTX is aware and manage the Link Training of the two DisplayPort Links, #1, the link between DPTX and DP In Adapter and #2, the link between DP Out Adapter and DPRX. The Link Training is done sequentially the upstream link (#1) first and the downstream link (#2) second. This mode is used when operating in LTTPR Non-transparent mode, see Section 10.4.10.1.

- Autonomous, Concurrent Link Training – In this mode the DPTX does not manage the Link Training between DP Out Adapter and DPRX; rather, it manages only the Link Training to the DP IN Adapter. In parallel to the training between the DPTX and DP In Adapter, DP OUT Adapter manages the link training to DPRX. DP In Adapter indicates the upstream Link Training completion only after it is notified of the downstream Link Training completion by DP Out Adapter, ensuring the end-to-end Link Training completion by the time DPTX exits Link Training sequence. This way of Link Training is used when operating in Non-LTTPR and LTTPR Transparent modes, see Section 10.4.10.2.

Aux Transaction handling has two major aspects to attend when executed over the tunnel:

- AUX Transaction initiation operates in two ways:

- o DPTX Only – In this mode only DPTX initiates AUX Transactions. This mode is used when operating in LTTPR Non-transparent mode.

- o DPTX and DP OUT Adapter – In this mode both, the DPTX and the DP OUT Adapter, are initiating AUX Transactions. A DP OUT Adapter mainly initiate AUX Transactions as part of the autonomous and concurrent Link Training Process. This mode is used when operating in Non-LTTPR and LTTPR Transparent modes, see Section 10.4.4.2.3 and Section 10.4.4.3.3 respectively.

- Timeout and DEFER usage:

  - o Allowed – A DP IN Adapter uses timeout to govern the AUX Link and uses AUX DEFER when timeout expires. This mode is used when operating in Non-LTTPR mode, see Section 10.4.4.2.1.

  - o Disallowed – A DP IN Adapter does not activate a timeout for AUX Responses, will not send DEFER and will not gate AUX Responses coming from DPRX. This mode is used when operating in LTTPR Non-transparent and LTTPR Transparent modes, see Section 10.4.4.3.1.

Table 10-1 summarizes the above modes of operations.

Table 10-1 DisplayPort Modes Of Operation Over DisplayPort Tunneling

Mode	Link Training	AUX Transaction Initiation	AUX DEFER Usage
Non-LTTPR	Autonomous, Concurrent	DPTX and DP OUT Adapter	Allowed
LTTPR Transparent	Autonomous, Concurrent	DPTX and DP OUT Adapter	Disallowed
LTTPR Non-transparent	DPTX Managed, Sequential	DPTX Only	Disallowed

After reset, a DP Adapter shall operate in Non-LTTPR mode. A DP Adapter shall transition among the three modes between Non-LTTPR mode and LTTPR mode as described in Section 10.4.6.1. A DP Adapter shall transition to Non-LTTPR mode upon exit from the Paired state.

Unless otherwise stated, the requirements in this chapter apply to DP Adapters in all three both LTTPR and Non-LTTPR modes.

10.3.1.1   LTTPR Non-transparent

A DP IN Adapter shall implement LTTPR Non-transparent UFP. A DP OUT Adapter shall implement LTTPR Non-transparent DFP. LTTPR Non-transparent UFP and LTTPR Non-transparent DFP are defined in the DisplayPort 1.4a Specification.

10.3.1.2   Non-LTTPR

A DP IN Adapter shall implement Non-LTTPR UFP. A DP OUT Adapter shall implement Non-LTTPR DFP. In Non-LTTPR mode, unlike LTTPR Non-transparent mode, the DPTX is unaware of the existence of additional DP Links. From the DPTX point of view, each operation appears to be carried out as if the DPRX is were directly attached to the DPTX. Non-LTTPR behavior is defined for AUX Handling in Section 10.4.4.2, Link Training in Section 10.4.10.2, and Connection Manager Discovery in Section 10.3.4.

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10.3.1.3   LTTPR Transparent

Operating in LTTPR Transparent mode (i.e. handling AUX transactions and performing Link Training) is the same as operating in Non-LTTPR mode with the following exceptions:
- The timeouts and timers are different
- The DP IN Adapter does not send AUX DEFER as is the case with LTTPR Non-transparent mode and does not gate AUX Transactions (see Section 10.4.4.2.2) except during autonomous, concurrent Link Training operation

(c). SET CONFIG Section 10.3.4.2.3 and Table 1-5

10.3.4.2.3 SET_CONFIG Packet

- **Training Pattern Support (TPS) [15:14]**: This field shall specify the supported TPS which can be used in EQ Phase in Non-LTTPR and LTTPR Transparent link training.

Table 10-5. SET_CONFIG Message

MSG Type	Type Value	Direction	MSG Data	Reference
SET_LINK	0x01	Both	[0] – DP Link Training Mode 0b: Autonomous, concurrent (applicable to Non-LTTPR and LTTPR Transparent) 1b: DPTX-managed, sequential (applicable to LTTPR Non-transparent) [7:1] – Reserved	Section 10.4.10 Section 10.4.12
SET_LTTPR_AWARE MODE	0x17	IN to OUT	[0] – LTTPR_AWAREMode 0: DPTX is LTTPR unawareLTTPR Transparent 1: DPTX is LTTPR awareLTTPR Non-Transparent [7:1] – Reserved	Section 10.4.4.2.110.4.6.1
SET_TRAINING	0x18	IN to OUT	[7:0] – Training Stage (TS) 0h: Training Done with DPRX 1h: TPS1 2h: TPS2 3h: TPS3 7h: TPS4 FFh: Training Done With LTTPR Non-transparent UFP All other values are Reserved	Section 10.4.10.1

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(d). Section 10.4.4.1 - LTTPR Mode

10.4.4.1 LTTPR Non-transparent Mode

This section defines the AUX Request and Response handling by DP Adapters operating in LTTPR Non-transparent mode.

(e). Section 10.4.4.2 - Non-LTTPR Mode

10.4.4.2.1 AUX Timeout Timers

~~By default the~~ The AUX Response Timeout timer in a DP IN Adapter shall be set to 300us.

~~When a DP IN Adapter receives the first AUX Request to the LT-tunable PHY Repeater DPCD Capability and ID Field and if the DP_COMMON_CAP.LTTPR Not Supported is set to 0b, a DP IN Adapter shall:~~

~~Set the AUX Response Timeout timer to 3.2ms.~~

- ~~Send a SET_CONFIG Packet of type SET_LTTPR_AWARE with LTTPR_AWARE bit set to 1b.~~

~~By default the~~ The AUX Reply Timeout timer in a DP OUT Adapter shall be set to 400us.

~~A DP OUT Adapter that receives a SET_CONFIG Packet of type SET_LTTPR_AWARE with the LTTPR_AWARE bit set to 1b shall set the AUX Reply Timeout timer to 3.2ms.~~

~~Figure 10-14. Example DP Source Discovery Sequence~~
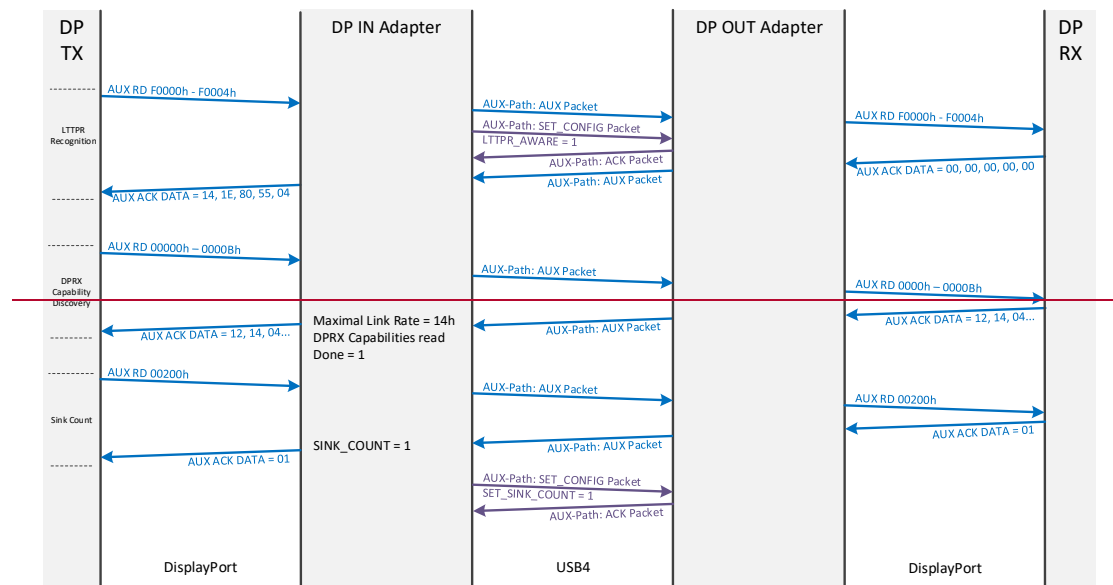
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10.4.4.2.2 DP IN Adapter Requirements

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A DP IN Adapter shall not send to a DP OUT Adapter an AUX Request while an AUX Reply to preceding another AUX Request is outstanding.

10.4.4.2.3 DP OUT Adapter Requirements

In a Non-LTTPR system, aA DP OUT Adapter handles two types of AUX Transactions:

- DPTX initiated.

- DP OUT Adapter initiated.

A DPTX initiated AUX Request has higher priority than a DP OUT Adapter initiated AUX

Transaction.

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10.4.4.2.3.2 DP OUT Adapter Initiated AUX Transactions

A DP OUT Adapter in Non-LTTPR mode initiates AUX Transactions for:
- Autonomous, concurrent Link Training.
- Down-Spread Control access, see Section 10.4.7.

10.4.4.3 LTTPR Transparent Mode

This section defines how a DP Adapter, operating in LTTPR Transparent mode handles AUX Requests and Responses. A DP IN Adapter shall implement AUX Slave (AUX CH Replier). A DP OUT Adapter shall implement AUX Master (AUX CH Requester).

10.4.4.3.1 AUX Timeout Timers

The AUX Response Timeout timer in a DP IN Adapter shall not be activated

The AUX Reply Timeout timer in a DP OUT Adapter shall be set to 3.2ms.

10.4.4.3.2 DP IN Adapter Requirements

A DP IN Adapter that receives an AUX Request shall classify the AUX Transaction as one of the three following types:
1. Internal AUX Transaction – AUX Request which targets only DPCD addresses that are defined as internal in Table 10-8.
2. External AUX Transaction – AUX Request which targets only DPCD addresses that are not defined as internal in Table 10-8.
3. Combined AUX Transaction – AUX Request which targets both Internal and External DPCD addresses. The AUX Response is initially generated by the DPRX and altered by the DP IN Adapter.

Note: A DP IN Adapter may assume that an AUX Write Request is not classified as a Combined Aux Transaction.

For External and Combined AUX Transactions, a DP IN Adapter shall send the AUX Request downstream to the DP OUT Adapter.

A DP IN Adapter shall:
- Not generate AUX DEFER
- Not gate any External or Combined AUX Request sent by the DPTX
- Not gate any AUX Response sent by the DPRX.

Note: DPTX enabling LTTPR Transparent mode shall support AUX Reply Timeout of 3.2ms as described in the DisplayPort 1.4a Specification. Once DPTX enables LTTPR Transparent mode, it is the responsibility of DPTX to manage the AUX Requests and AUX Responses, not DP In Adapter.

10.4.4.3.3 DP OUT Adapter Requirements

A DP OUT Adapter handles two types of AUX Transactions:

- DPTX initiated.

- DP OUT Adapter initiated.

A DPTX initiated AUX Request has higher priority than a DP OUT Adapter initiated AUX Transaction.

A DP OUT Adapter that receives a DPTX initiated AUX Request while handling a DP OUT Adapter Initiated AUX Transaction, shall send the DPTX initiated AUX Request as soon as it is in Talk Mode.

10.4.4.3.3.1 DP TX Initiated AUX Transactions

A DP OUT Adapter that receives an AUX Request from a DP IN Adapter shall initiate the AUX Request as soon as it is in Talk Mode.

A DP OUT Adapter that receives an AUX Response shall send the AUX Response over the AUX Path to the DP IN Adapter.

If the AUX Reply Timer expires before an AUX Response is received, a DP OUT Adapter shall send a SET_CONFIG of type SET_AUX_INIT and shall not retry the AUX Request.

10.4.4.3.3.2 DP OUT Adapter Initiated AUX Transactions

A DP OUT Adapter initiates AUX Transactions for:
- Autonomous, concurrent Link Training.
- Down-Spread Control access, see Section 10.4.7.

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(f). Table 10 11. Aggregated DisplayPort Capabilities

| DPCD Register (Address)	DPCD Field Name	DisplayPort Capability
DPCD_REV (0000h / 02200h / F0000h)	Major Revision Number	max{12h, min [Downstream response, DP_COMMON_CAP.*Maximal DPCD Rev.*].
MAX_LINK_RATE (00001h / 02201h / F0001h)	MAX_LINK_RATE	Minimum of downstream response and DP_COMMON_CAP.*Maximal Link Rate.*
MAX_LANE_COUNT (00002h / 02202h / F0004h)	MAX_LANE_COUNT	Minimum of downstream response and DP_COMMON_CAP.*Maximal Lane Count*. If MFDP Mode is set, then Maximum is 2.
	POST_LT_ADJ_REQ_ SUPPORTED	~~If in Non-LTTPR mode, set to zero.~~ If in LTTPR Non-transparent mode, this field is unchanged. Else set to zero.
TRAINING_AUX_RD_INTERVAL (0000Eh / 0220Eh)	TRAINING_AUX_RD_ INTERVAL	If in LTTPR Non-transparent mode, this field is unchanged. Else~~If in Non-LTTPR mode~~, the downstream response is either unchanged or the DP IN Adapter may increase the value. Note that per DP v1.4a, the maximum value for this field is 4h. ~~If in LTTPR mode, this field is unchanged.~~

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(g). Figure 10-17 Example DP Source Discovery Sequence

Editorial Note for the figure: Change the LTTPR_AWARE = 1 to LTTPR_Mode = 0

Figure 10-17. Example DP Source Discovery Sequence
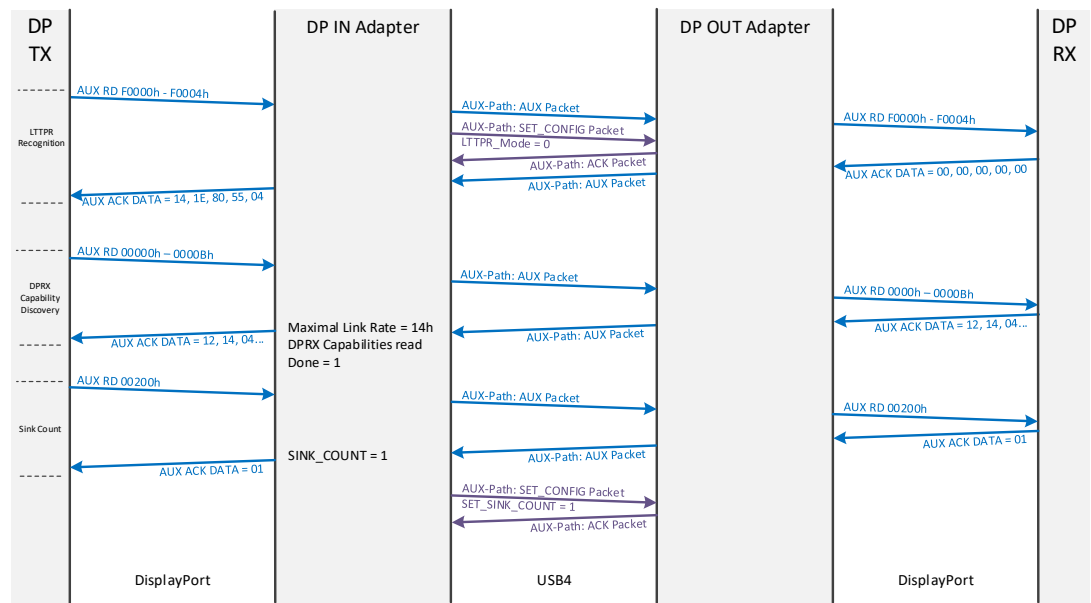
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(h). Section 10.4.6.1 LTTPR Recognition and Modes Change

10.4.6.1 LTTPR Recognition and Modes Change

A DPTX performs an AUX read from the *LT-tunable PHY Repeater DPCD Capability and ID* Field to discover the presence, count and capabilities of any downstream LTTPR. A DP IN Adapter shall modify the resulting AUX read response as defined in Section 10.4.4.4.

This action of AUX read from LT-tunable PHY Repeater DPCD registers by DPTX prompts DP Adapter to transition from Non-LTTPR mode to LTTPR mode. Upon transition to LTTPR mode, DP Adapter is in LTTPR Transparent mode by default. DPTX may prompt the transition to LTTPR Non-transparent mode and back to LTTPR Transparent mode by setting PHY_REPEATER_MODE register at DPCD F0003h, 55h for LTTPR Transparent mode and AAh for LTTPR Non-transparent mode. ~~After discovering a downstream LTTPR, the DPTX can set the LTTPR chain to Non-Transparent or Transparent mode. This transitions a DP IN Adapter between LTTPR and Non-LTTPR modes as follows:~~

~~If a DP IN Adapter is in Non-LTTPR mode and a DPTX sets the PHY_REPEATER_MODE to Non-Transparent mode (AAh), a DP IN Adapter shall transition to LTTPR mode. The DP IN Adapter shall complete the AUX Transaction which sets the PHY_REPEATER_MODE to Non-Transparent mode as a Non-LTTPR mode AUX transaction.~~

~~If a DP IN Adapter is in LTTPR mode and a DPTX sets the PHY_REPEATER_MODE to Transparent mode (55h), a DP IN Adapter shall transition to Non-LTTPR mode. The DP IN Adapter shall complete the AUX Transaction which sets the PHY_REPEATER_MODE to Transparent mode as an LTTPR mode AUX transaction.~~

If DP_COMMON_CAP.*LTTPR Not Supported* is set to 1b, a DP Adapter shall operate only in Non-LTTPR mode. Otherwise it transitions between the three operation modes according to Table 10-13.

Table 10-13 DP Adapter Operation Mode Transitions

Mode	DP IN Adapter	DP OUT Adapter
Non-LTTPR	Adapter has exited the Paired State	Adapter has exited ~~tin~~ the Paired State or Adapter received a SET CONFIG Packet of type SET_AUX_INIT
LTTPR Transparent	Adapter receives first DPTX access to the *LT-tunable PHY Repeater DPCD Capability and ID* Field or DPTX changes the PHY_REPEATER_MODE to Transparent mode (55h)	Adapter received a SET CONFIG Packet of type SET_LTTPR_MODE with *LTTPR_Mode* set to 0b
LTTPR Non-Transparent	DPTX changes the PHY_REPEATER_MODE to Non-Transparent mode (AAh)	Adapter received a SET CONFIG Packet of type SET_LTTPR_MODE with *LTTPR_Mode* set to 1b

A DP IN Adapter shall do the following before transitioning to LTTPR Transparent mode~~-~~:

- Complete the AUX Transaction according to the current operation mode

- Send a SET CONFIG Packet of type SET_LTTPR_MODE with LTTPR_Mode set to 0b

A DP IN Adapter shall do the following before transitioning to LTTPR Non-transparent mode ~~it shall~~:

- Complete the AUX Transaction according to the current operation mode

- Send a SET CONFIG Packet of type SET_LTTPR_MODE with *LTTPR_Mode* set to 1b

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(i). Section 10.4.7 Down-Spread Control

When DPCD address 00107h is written by a DPTX, a DP IN Adapter, operating in Non-LTTPR or LTTPR Transparent modes, shall respond with AUX ACK and shall send a SET_CONFIG Packet of type SET_DOWNSPREAD. The *MSG Data* field in the SET_CONFIG Packet shall be equal to the value written by the DPTX.

(j). Section 10.4.10.1   LTTPR

10.4.10.1 LTTPR Non-transparent

The DP IN and DP OUT Adapters shall follow the LTTPR Non-transparent link training as defined in the DisplayPort 1.4a Specification while noting the following points:

- DP IN as UFP and DFP – As described in Section 10.4.4, the DP IN Adapter serves as UFP and DFP for AUX handling, therefore it updates the DP OUT Adapter with the different stages of the LTTPR Non-transparent link training through SET_CONFIG Packets.

- Training Patterns – Training Patterns are not carried over the USB4 Fabric.

10.4.10.1.1 DP IN Adapter Requirements

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- A DP IN Adapter shall send a SET_CONFIG Packet of type SET_LINK after DPTX writes TPS1 to the DP IN Adapter TRAINING_PATTERN_SET_PHY_REPEATERx DPCD register. The SET_CONFIG packet shall have the following values:
    - LC = LANE_COUNT_SET value written by DPTX.
    - LR = LINK_BW_SET value written by the DPTX.
    - MSG Data = 1b, representing *DP Link Training Mode* = LTTPR Non-transparent.

(k). Section 10.4.10.1.2 DP OUT Adapter Requirements

- A DP OUT Adapter that receives a SET_CONFIG Packet of Type SET_LINK with *DP Link Training Mode* bit set to 1b shall:

- Transition to LTTPR mode.

   Start its internal Symbol clock PLL according to the *Link Rate* field, and start the Lifetime Counter as defined in Section 10.6.1.2.

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(l). Section 10.4.10.1.3 DP Link Training Example

The DP Link Training process in this section describes a system which, from the DisplayPort point of view, consists of DPTX, DPRX and one LTTPR in LTTPR Non-transparent mode. The DPRX's maximum supported link rate is HBR2, and it does not support TPS4. The DPTX establishes a DP Link of 2 lanes at HBR2 link rate.

10.4.10.1.3.1 LTTPR – CR_DONE Phase

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    3. DP OUT Adapter Initiation

- A DP IN Adapter sends SET_CONFIG Packet of type SET_LINK, carrying the DP Link training parameters and *DP Link Training* Mode = 1b.

(m). Section 10.4.10.2 Non-LTTPR

10.4.10.2 Non-LTTPR **and LTTPR Transparent**

10.4.10.2.1 DP IN Adapter Requirements

- MSG Data = 0b, representing *DP Link Training* Mode = Non-LTTPR and LTTPR Transparent modes.