Link Initialization Protocol

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Scope and Purpose

- This presentation describes a generic version of the Link Initialization Protocol (LIP) that is independent of line code.
  - First introduced in http://ieee802.org/3/ap/public/jul04/brink_02_0704.pdf
- This presentation compares LIP to alternate approaches to link start-up.

Agenda

- **Start-Up Protocol Wish List**
- Review of Link Initialization Protocol
- Solution Comparison and Recommendations

Start-Up Protocol Benefits

- Optimizes transmitter FIR.
- Automatic power control.
  - Receiver may steer the transmitter output voltage to the minimum level required for acceptable performance.
  - May also mitigate crosstalk.
- Optimize receiver equalizer.
  - Joint adaptation of transmitter and receiver yields superior solution to independent adaptation.
- Benefits apply equally to PAM-2, PAM-4, PR-2, or PR-4.

Start-Up Protocol Wish List

- Simple.
- Robust and Reliable.
- Interoperable.
- Fast convergence time.
  - Minimize time from connection to full link operation.

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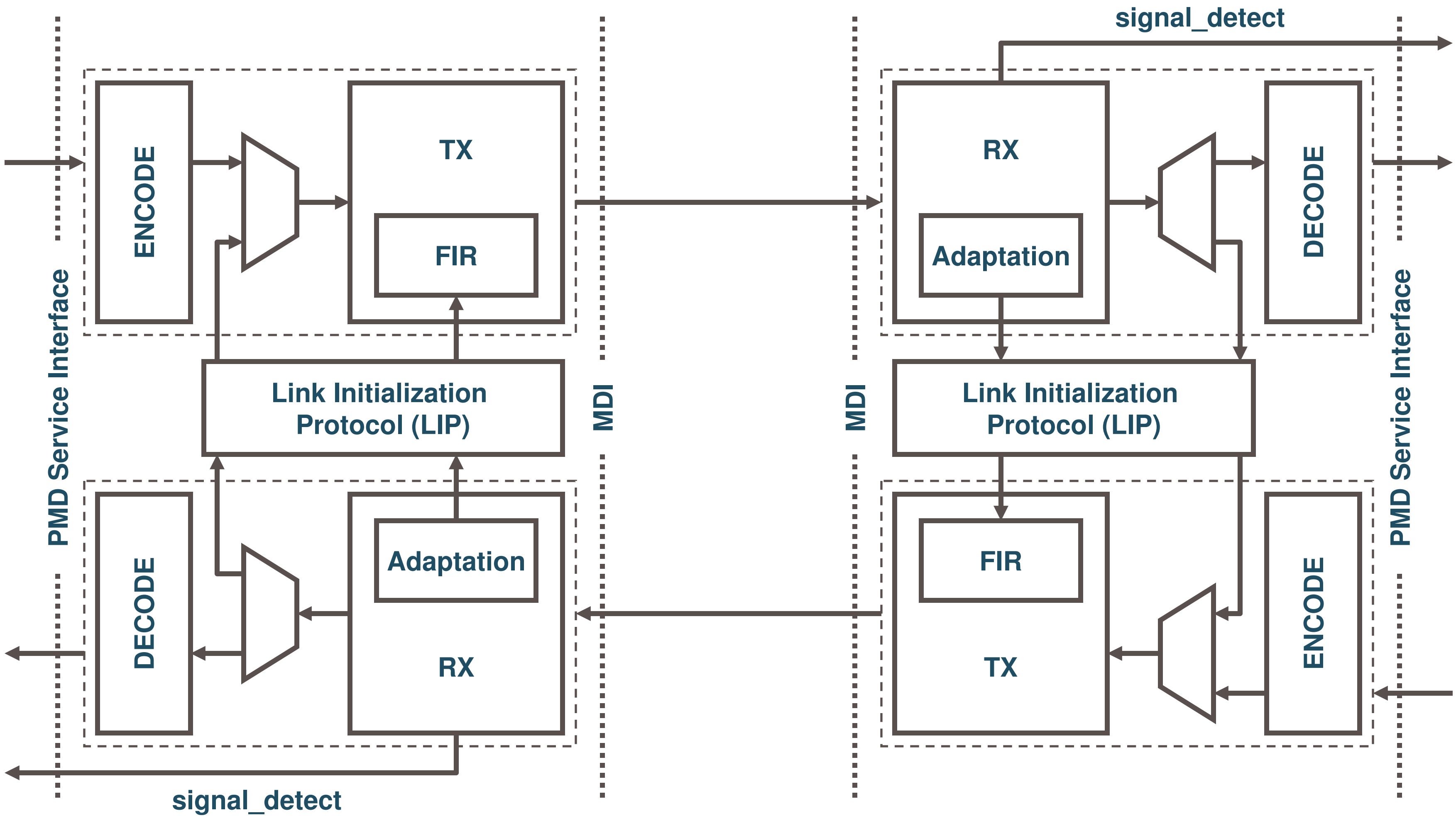
- **Review of Link Initialization Protocol (LIP)**
- Solution Comparison and Recommendations

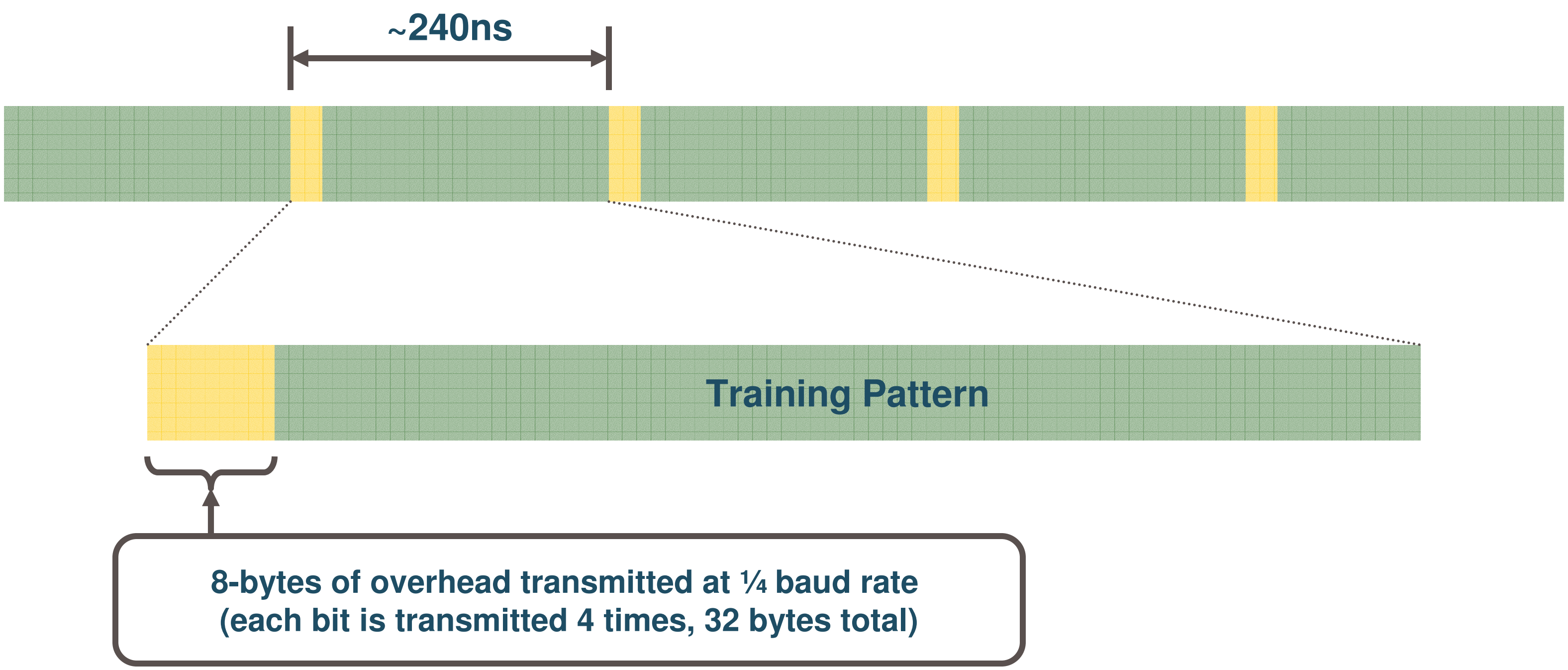
Link Model



signal_detect
PMD Service Interface
ENCODE
TX
FIR
Link Initialization
Protocol (LIP)
DECODE
Adaptation
RX
signal_detect
MDI
MDI
RX
Adaptation
DECODE
Link Initialization
Protocol (LIP)
FIR
TX
ENCODE
PMD Service Interface

LIP Frame Format

- Frame length is 2480 bits (310bytes).
  - Divisible by both 16 and 20.
  - 278-byte training pattern, 32 bytes of overhead.
  - 1 frame every ~240ns at 10.3125Gb/s

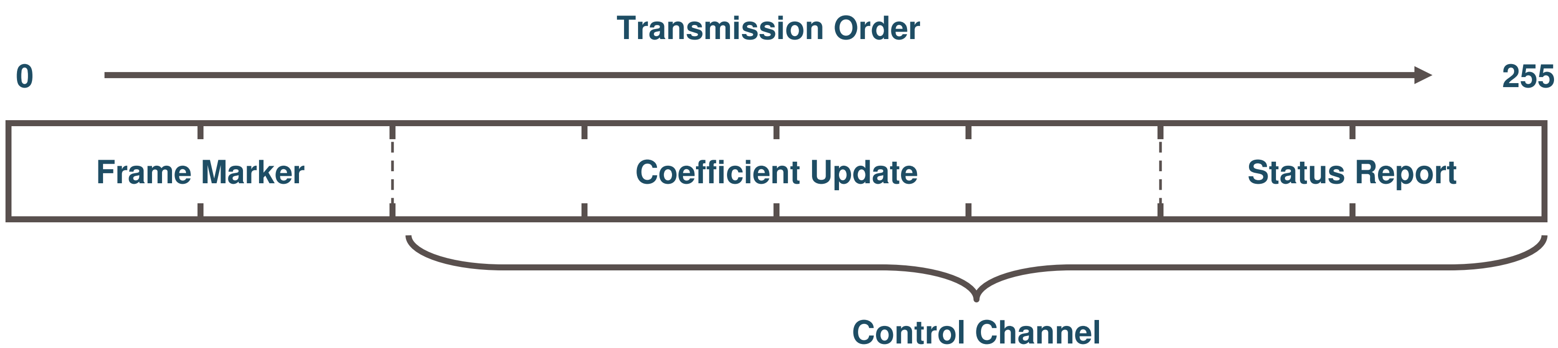


Training Pattern

- 278 bytes in length.
- Any DC-balanced “random” pattern will suffice.
- Training pattern must not contain the frame marker pattern or its inverse.

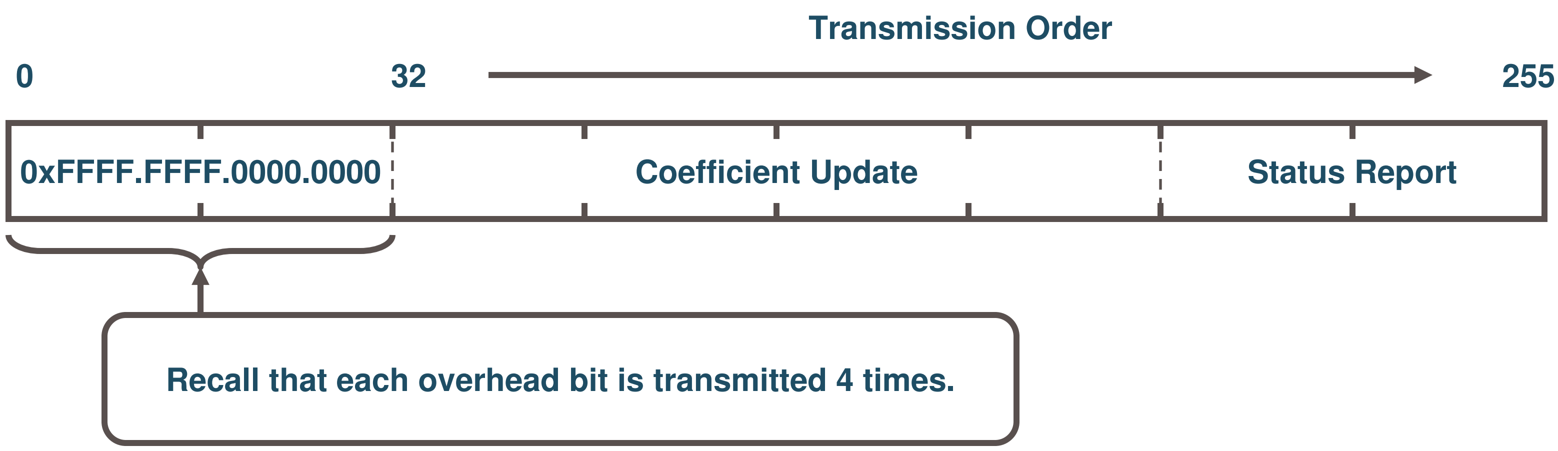
Overhead

- Transmitted at ¼ baud rate.
  - Each overhead bit is repeated 4 times.
- 2-byte Frame Marker (transmitted in 8 bytes)
- 6-byte Control Channel (transmitted in 24 bytes)



Frame Marker

- Delimits LIP frames.
- Fixed 2-byte pattern, 0xFF00
  - Detectable over unequalized or partially equalized channels.
  - Does not occur in control channel or training pattern.
  - Also may be used as a polarity check (reception of 0x00FF) indicates polarity reversal.



Control Channel

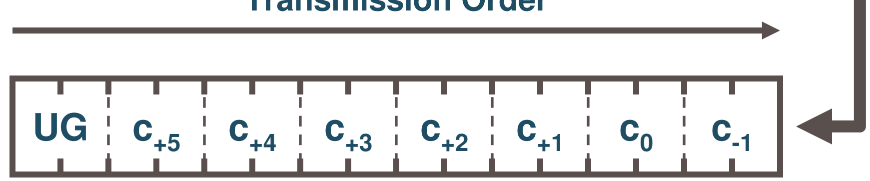
- 3-bytes of control information (6-bytes after encoding).
  - Coefficient update.
  - Status report.
- Manchester Coding
  - Guarantees 50% transition density.
  - Guarantees DC balance.
  - Prevents frame marker pattern from appearing in the control channel.
  - Detectable over unequalized or partially equalized channels.

Message Bit	Encoded Sequence
0	10
1	01

Coefficient Update (1/2)

- 2 bytes support parallel update of transmitter FIR coefficients to a maximum of 7 taps.
  - It is not necessary for an implementation to support all 7 taps.
  - Minimum number required to be determined via signaling simulation.
- Each tap has an associated action.
  - Decrement / Hold / Increment
  - Agnostic to the supported tap weight resolution.
  - Tolerant of corrupted or lost coefficient updates.
  - Actions applied to unsupported taps are ignored.

Action	Encoding
Hold	00
Decrement	01
Increment	10
Reserved	11



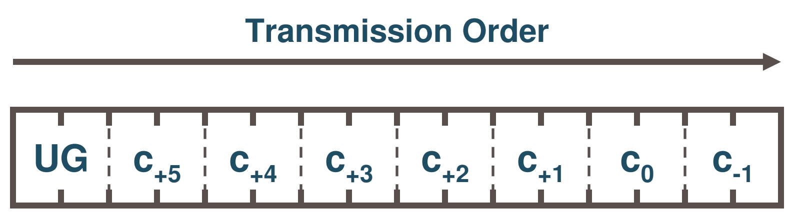
Notes

a) Fields shown prior to Manchester encoding.
b) By convention, c_0 is the main (or gain) tap.

Coefficient Update (2/2)

- Update Gain (UG)
  - Coefficient step size may be increased to speed convergence.
  - Large gain may used in initially, then decreased to 1X for finer tuning.

UG	Coefficient Step Size
00	1X
01	2X
10	4X
11	8X



Notes

a) Fields shown prior to Manchester encoding.

b) By convention, c_0 is the main (or gain) tap.

Status Report

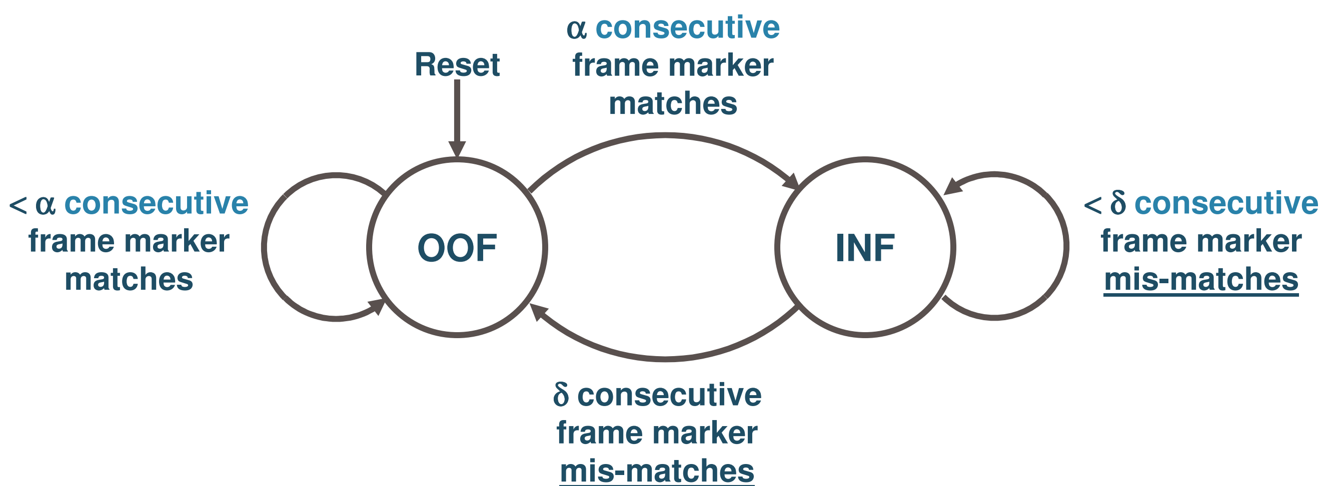
- Third byte in the control channel.
- *ReceiverReady* (RR) indicator (1-bit).
  - Asserted (1) when receiver deems that equalization training (for both the transmitter and receiver) is complete.

Notes

a) Fields shown prior to Manchester encoding.

Framing Algorithm

- The receiving framer is expected to implement a simple α–δ framing algorithm.
  - Upon reset the LIP receiver goes to the OOF (Out-of-Frame) state.
  - The LIP receiver shall transition from the OOF state to the INF (In-Frame) state after finding the frame marker, one frame apart for α (2) consecutive frame times.
  - The LIP receiver shall transition from the INF state to the OOF state if the frame marker is not found during δ (5) consecutive frames.



LIP Highlights

- Local receiver adaptation process sends FIR tap weight updates to the remote transmitter via the coefficient update field.
  - The adaptation process itself is beyond the scope of the standard.
  - A variety of algorithms may be employed.
- When the local adaptation process determines that the local Tx and remote Rx are fully trained, it sets the ReceiverReady bit on outgoing LIP frames.
  - The LIP state machine must see the ReceiverReady bit asserted three consecutive times before it concludes that the remote receiver is ready to receive data (no hair triggers).
- When the LIP state machine determines that the local and remote receivers are ready to receive data, it sends a fixed number of LIP frames to ensure that the remote receiver properly detects the ReceiverReady bit.

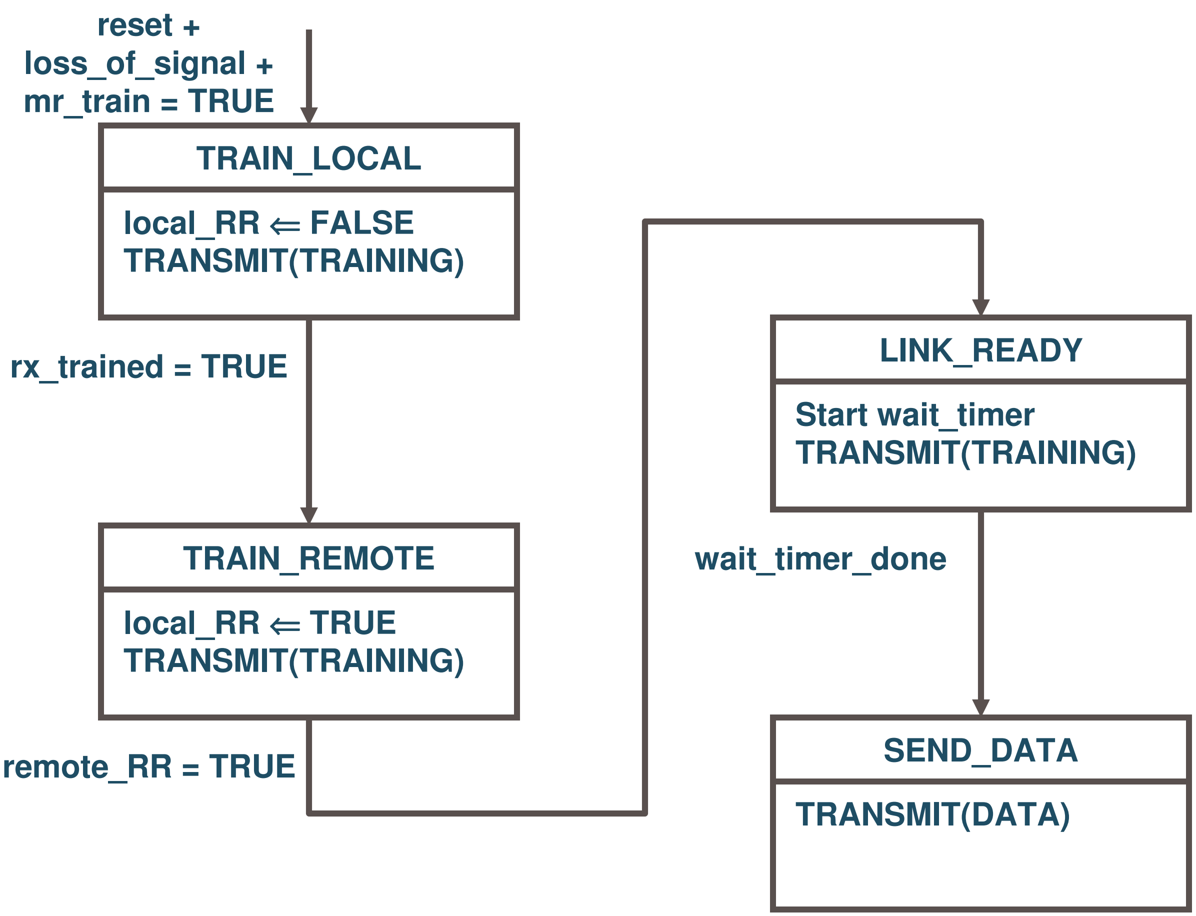
LIP State Diagram (1/3)

- Variables
  - reset: Condition that is true until such time as the power supply for the device has reached its specified operating region.
  - mr_train: Asserted by system management to initiate training.
  - local_RR: Asserted by the link initialization protocol state machine when rx_trained is asserted. This value is transmitted as the *ReceiverReady* bit on all outgoing LIP frames.
  - remote_RR: The value of remote_RR shall be set to FALSE upon entry into the TRAIN_LOCAL state. The value of remote_RR shall not be set to TRUE until no fewer than three consecutive LIP frames have been received with the *ReceiverReady* bit asserted.
  - rx_trained: Asserted when the transmit and receive equalizers have been optimized and the normal data transmission may commence.
  - loss_of_signal: De-asserted when the presence of an electrical signal is detected at the receiver. This is not an indication of the quality of the received signal (loss_of_signal = FALSE does not guarantee the signal is valid, only that that the peak-peak amplitude exceeds the specified value).

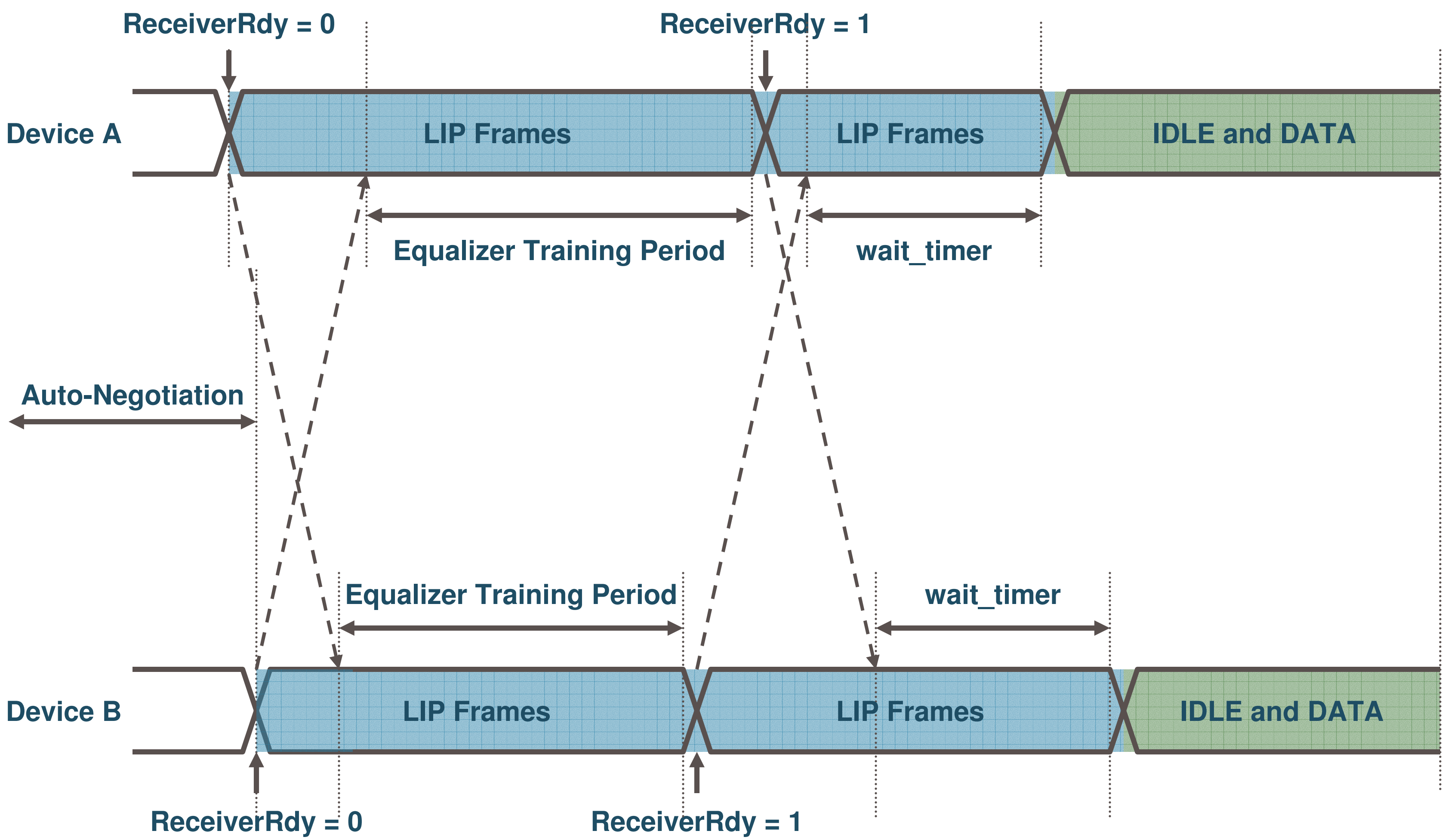
LIP State Diagram (2/3)

- Timers
  - **wait_timer: This timer is started when the local receiver detects that the remote receiver is ready to receive data. The local transmitter will deliver wait_timer additional LIP frames to ensure that the remote receiver correctly detects the *ReceiverReady* state. The value of wait_timer shall be between 100 and 300 LIP frames.**
- Messages
  - **TRANSMIT( )**
    - **TRAINING: Sequence of LIP frames. The coefficient update and status report fields are defined by receiver adaptation process.**
    - **DATA: Sequence of symbols as defined by the output of the ENCODE block.**

LIP State Diagram (3/3)

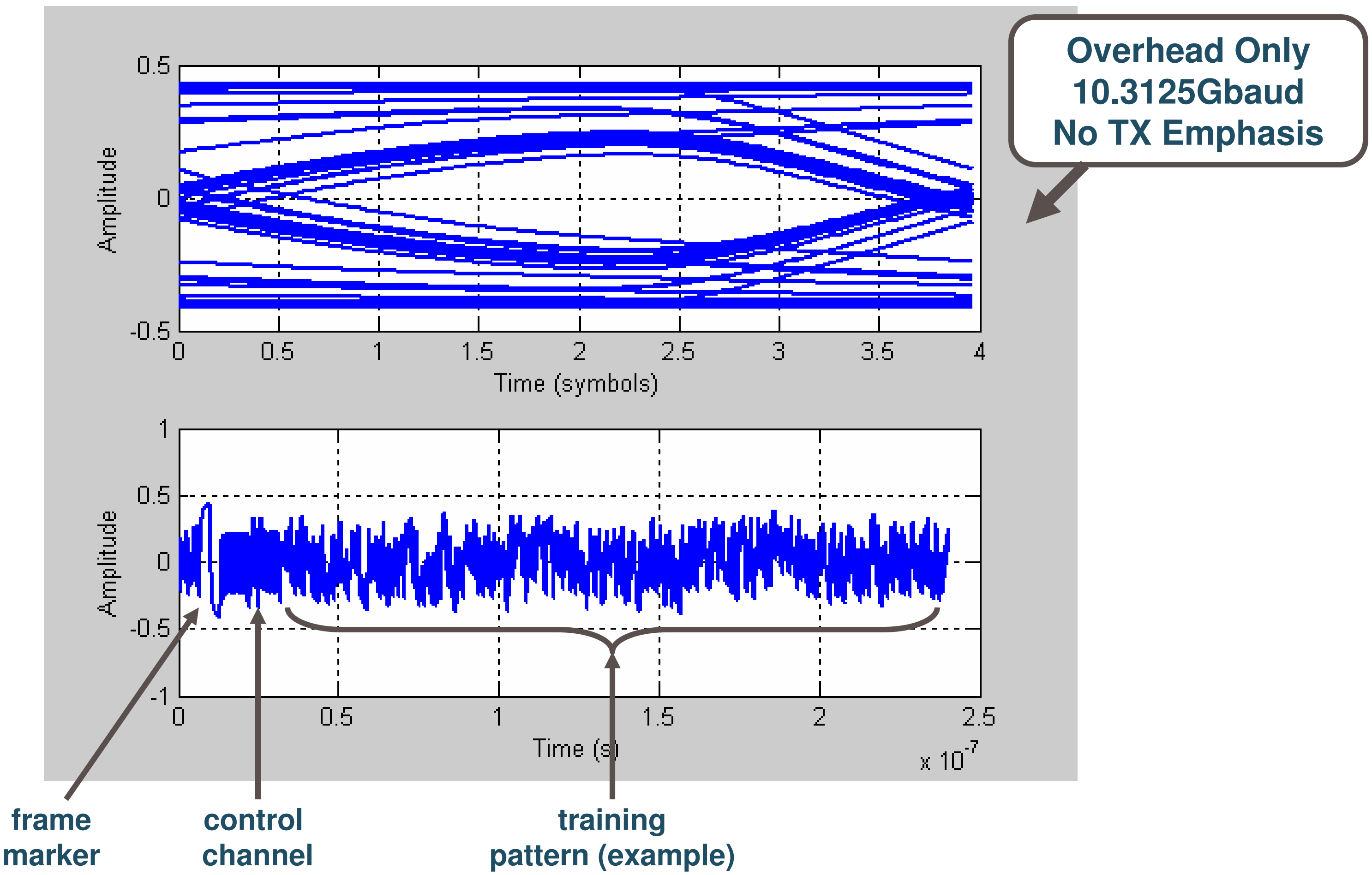


Example LIP Timing Diagram

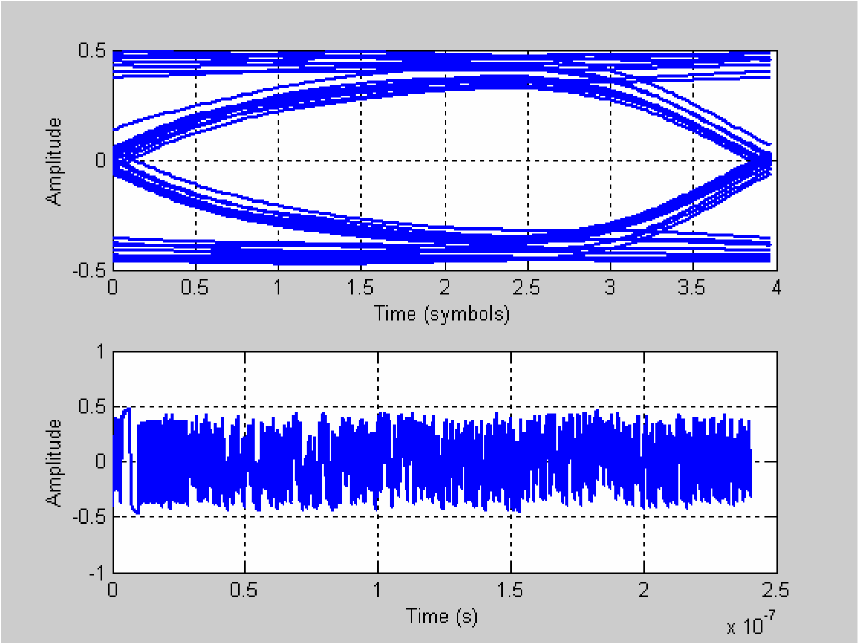


Robust Reception of LIP Frames (1/2)

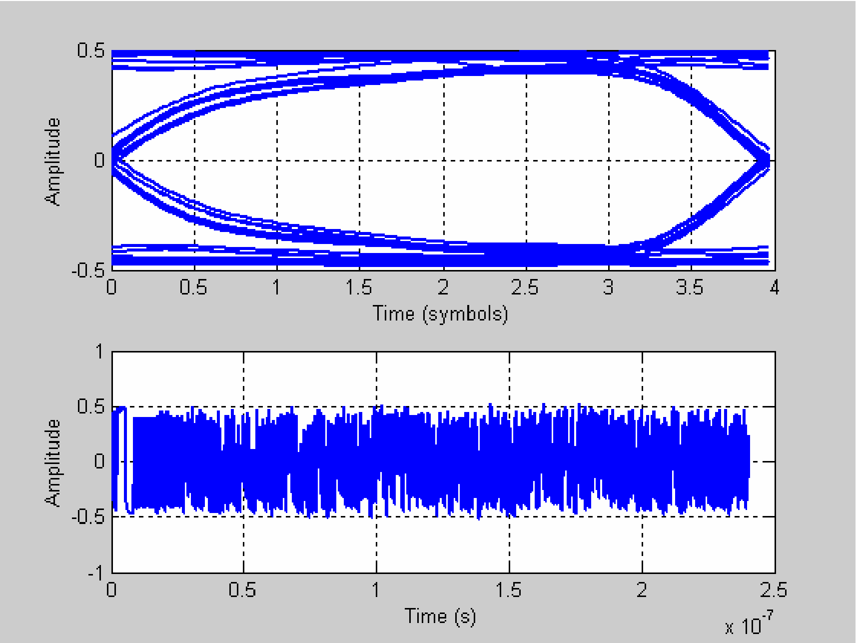
Tyco Test Case 3 (10” -6 Line Cards, 20” -13SI Backplane)



Robust Reception of LIP Frames (2/2)



Tyco Test Case 6
(6” -13 Line Cards, 10” -13 Backplane, stub)



Tyco Test Case 7
(6” -13SI Line Cards, 1” -13SI Backplane, stub)

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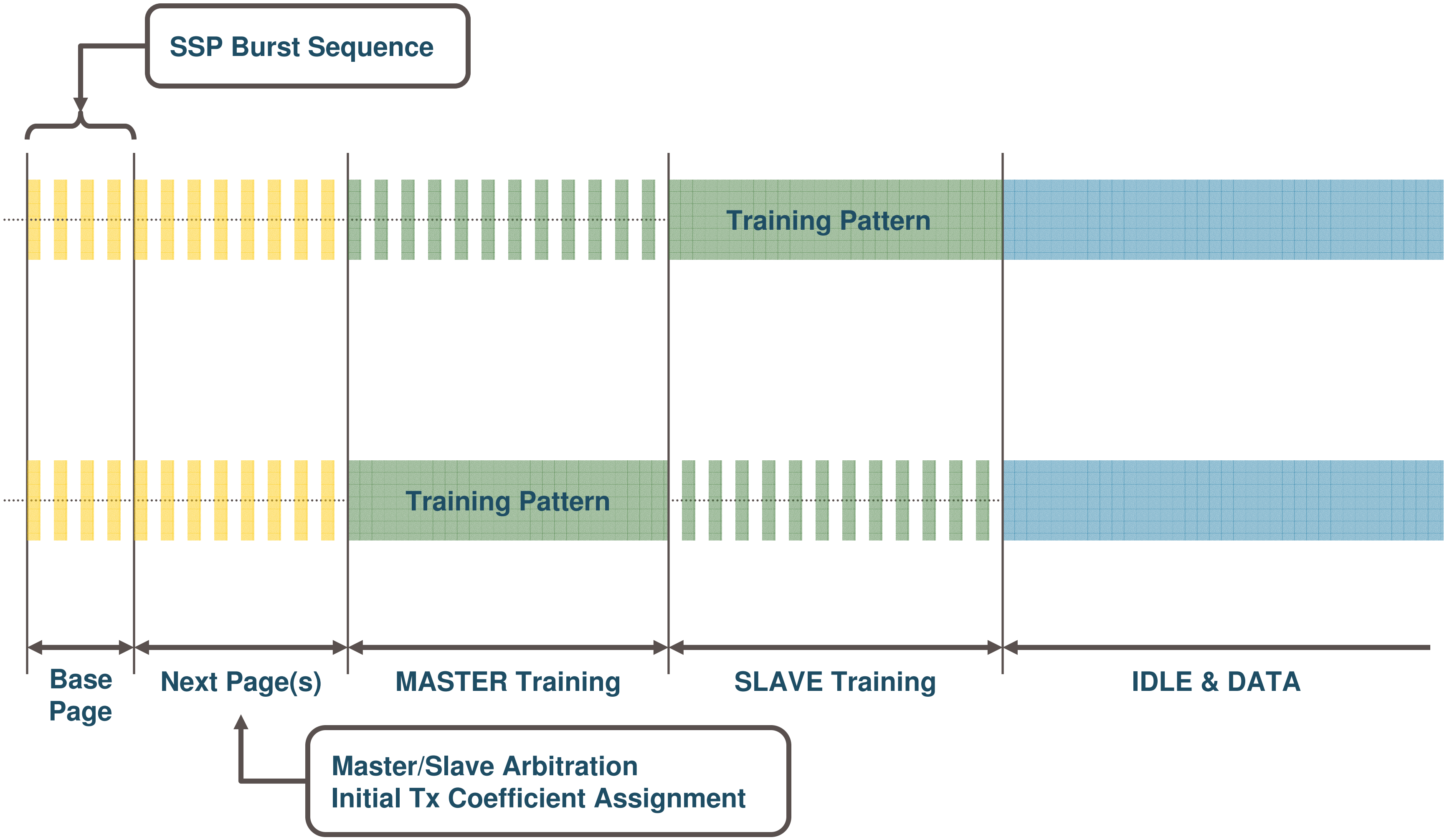
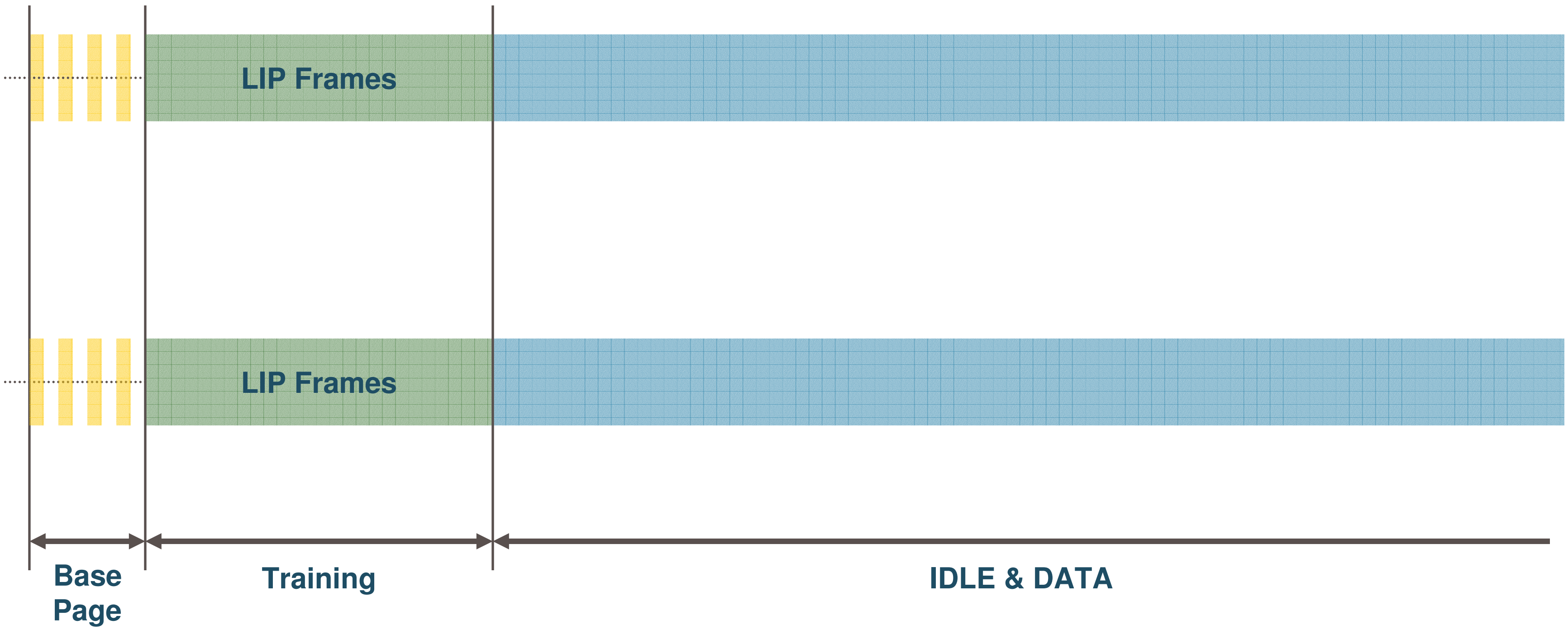
SSP-Based Training Timing Diagram



LIP Timing Diagram



SSP-Based Training

PRO:

- Very robust reverse channel signaling.
- Theoretically applies to all port types.
- Extensible via Auto-Negotiation Next Pages.

CON:

- Requires multiple Auto-Negotiation Next Page exchanges for Master-Slave arbitration and initial equalizer settings.
- Multi-phase start-up protocol.
- Longer time to convergence.
- More complex protocol = higher risk of interoperability problems.

Link Initialization Protocol (LIP)

PRO:

- Simple, single-phase start-up protocol.
- De-coupled from auto-negotiation. Clearly contained within the PMD sub-layer.
- Requires no next page exchanges (if auto-negotiation is enabled).
- Faster convergence time.
  - Rapid coefficient updates and simultaneous training of forward and reverse paths.

CON:

- Bound to 10GBASE-KR PMD, other port types require independent solutions.
- Limited room for expansion.

Conclusions

- Both approaches to link start-up can be made to work.
- SSP-based training provides robust reverse-path signaling that may be applied to all port types.
  - Is it necessary to be able to train on channels that cannot support the operating link rate? [No]
  - Do 1000BASE-KX and 10GBASE-KX4 require link start-up? [No]
- LIP provides a simpler alternative.
  - Fewer things can break. Easier to achieve interoperability.
  - More rapid convergence.
  - LIP can be shown to reliably solve backplane channels that support 10Gb/s operating rates.
- LIP is the preferred link start-up protocol, independent of line-code decision.

Thank You