Line Side Duplexing Options for ISAAC

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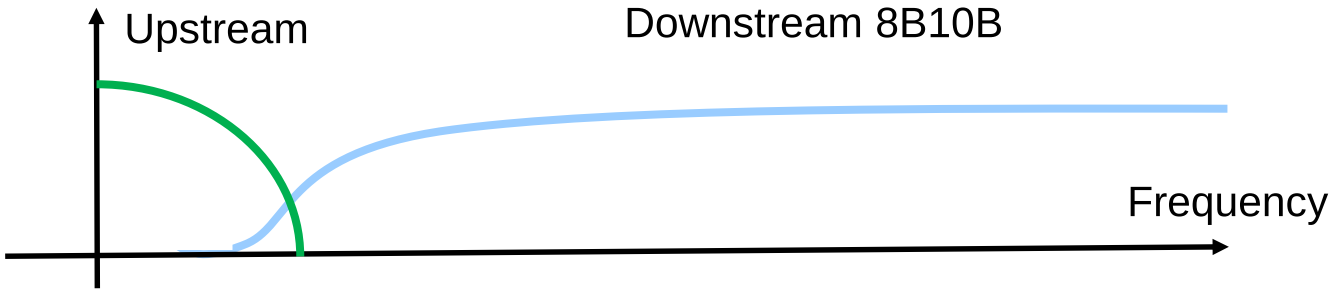
Problem Statement

- ISAAC study group is looking into technical feasibility of an Ethernet-based asymmetric physical layer that supports the Automotive Imaging Sensors.
- The Automotive Imaging Sensors have size and heat (power) limitation and typically use power over coaxial to receive power, video and the control data.
- The existing proprietary technologies run typically at 4 Gbps data rate or below over coaxial cables with solutions up to 6 Gbps available in the market place.
- ISAAC is looking into extending the data rate up to 10 Gbps while keeping the complexity and power low.
- This presentation highlights the basic properties of potential asymmetric PHY solutions.
- It is understood that the solutions are to be developed in the Task Force after many factors including cabling, power and sensor limits are analyzed and the challenges to interconnect with the existing Ethernet fabric are resolved.

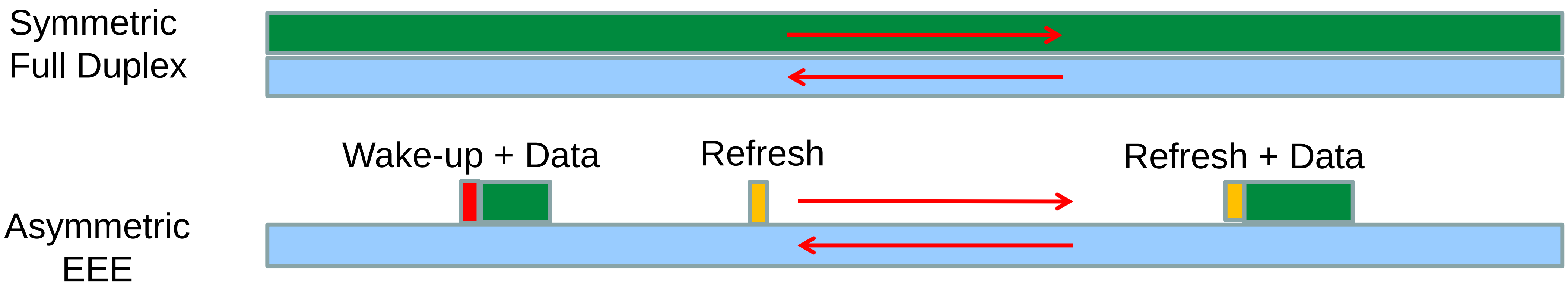
Frequency Division Duplexing (FDD)

- A typical FDD solution uses NRZ with 8B10B encoding which reduces the lower frequency band intensity of the downstream data. The lower frequency band is then used for upstream data transfer.



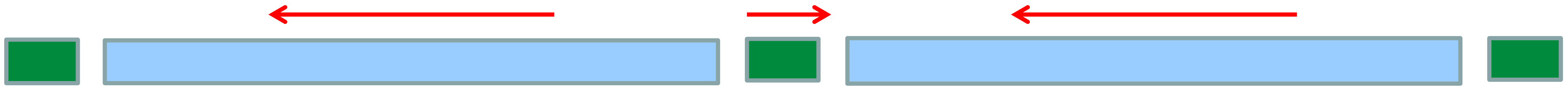
- FDD has 25% bandwidth expansion due 8B10B encoding. No systematic PHY layer latency.
- FDD solutions have been used for the automotive cameras up to 6 Gbps (typically, below 4 Gbps).
- Due to upstream band in low frequencies, FDD requires a relatively larger power coupling circuit.
- Given larger power coupling inductor, there is more power loss and more sensitivity to load variations (Ldi/dt).
- Typically, the existing FDD implementations only support point-to-point links.

Full Duplex (FDX) and EEE



- Random wake up and data transmit on upstream is to be conducted to support asymmetric data operation.
- However, the concurrent transmit and receive signaling requires echo cancellation (the echo canceller complexity significantly increases with higher data rates).
- Initially, the link is trained with symmetrical full duplex that requires more power than EEE. Therefore, the BOM has to be designed to support peak power which increases the cost.
- The transmit and receive data have same baud rate (ISAAC is cost and power sensitive mainly on the camera side).
- A precise clocking is required on both sides of the link (for echo cancellation).

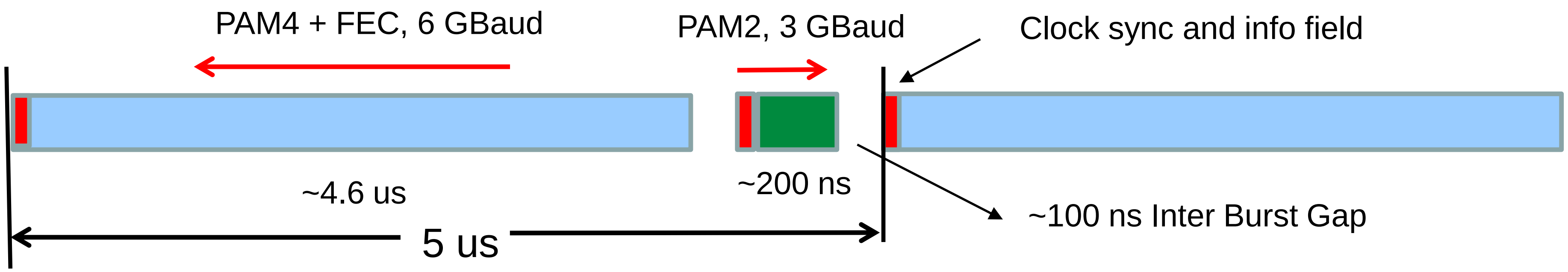
Time Division Duplexing (TDD)



- Similar to EEE, TDD is scalable for data rate with the following differences:
  - Periodically, TDD alternates direction of data transmit to accommodate a short upstream duration.
  - No overlap between transmit signal and receive signal. Therefore, there is no need for the echo cancellation.
  - Link up and Normal mode power are about the same (helps with BOM optimization)
  - Transmit and receive data may have different baud rates. Lower baud rates may be used for upstream to help with reduced cost and power of the receiver in the camera.
  - With a proper specification, the camera transmitter may extract its accurate clock from the remote ECU instead of a local crystal and hence, more cost savings can be achieved.
- Compared to FDX, it allows for smaller size and lower power loss in the power coupling circuit (Automotive cameras have small enclosures and they are heat limited). It is also less sensitive to return loss and transient noises that are seen in lower frequencies.

Simplified Example of a TDD Cycle

- TDD cycle may be assumed as low as 5 uS or even lower to achieve better latency, or larger durations for better bandwidth efficiency.
- Consider downstream rate of 10 Gbps and upstream rate of 100 Mbs.
- Downstream and upstream may use different baud rates and different error correction capabilities.



- Bandwidth expansion from TDD: ~8% (further reduced with longer TDD cycles)
- Latency from TDD: 0.4 us downstream and 4.8 us upstream (60 Bytes)
- Upstream use of PAM2 and lower baud rate is to reduce cost and complexity of the camera receiver.
- FIFOs may be used on a TDD link to convert it into uninterrupted continuous 10 Gbps downstream.

Summary

- There are multiple solutions available to support the asymmetric PHY objectives of ISAAC.
- This presentation provides a high level introduction to possible duplexing solutions at the PHY layer. TDD scheme provides a promising option.
- It is understood that more details need to be discussed and analyzed before a consensus solution can be achieved during Task Force. Here are a few starting topics for discussion :
  - The link segment’s performance for coaxial and STP cabling needs to be discussed.
  - Power over Coaxial and Power over STP need to be discussed.
  - The PHY requirements to support video and control signaling (e.g., I2C) should be analyzed.
  - The existing automotive camera solutions’ fundamentals and limitations should be reviewed.
  - Higher layer latency (e.g. when passing through an Ethernet switch, IEEE 1722) should be analyzed to give us a perspective on latency.

Thank you!