100G backplane PHY: NRZ and PAM4

Matt Brown

802.3bj Task Force

IEEE 802.3 Interim September 2011

Contributors and Supporters

- Richard Mellitz, Intel Corp.
- Howard Frazier, Broadcom
- Will Bliss, Broadcom
- Sudeep Bhoja, Broadcom
- Kent Lusted, Intel Corp.
- Vasu Parthasarathy, Broadcom
- Marek Hajduczenia, ZTE Corp.
- Adam Healey, LSI
- George Noh, Vitesse
- Venkatesh Nagapudi, APM
- Dariush Dabiri, APM
- Tim Warland, APM

Agenda

- Disparate backplane applications
  - “improved” versus installed base backplanes
- Define one or two PHY types
- Compare NRZ and PAM4
- Dual PHY definitions

Two target applications/markets

- Two disparate target applications for a 100G backplane PHY.
  - Installed base of backplanes designed for 40GBASE-KR4 and compliant to 802.3ba Clause 69B.
  - New generation backplanes designed with “improved” components, materials, and construction.
- Opposing requirements for each backplane application:
  - New generation backplanes are compatible with higher efficiency, mixed signal PHY due to improved channel characteristics.
  - Installed base backplanes require more bits per baud and more sophisticated signal processing due to lower bandwidth and more challenging channel characteristics.

Why support installed base?

- Prior to and including 802.3ap, each new generation of backplane PHY stranded a subset of installed base.
- However, 802.3ba leveraged the backplane definition in 802.3ap to define a new 40G backplane.
- As a result, we have a growing installed base of backplanes conforming to a common standardized set of requirements.
- Presentations have shown that backplanes meeting these requirements with small modifications have ample bandwidth for 100G given appropriate signaling techniques.
- The large numbers of these installed backplanes and well known requirements for these backplanes make it both practical and profitable to address.

Options

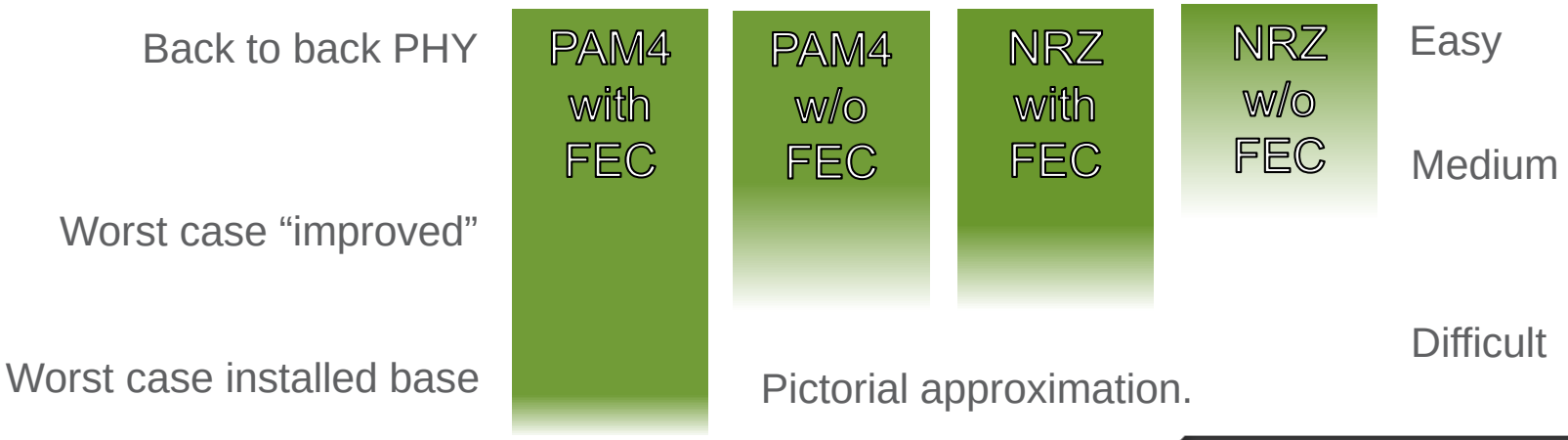
- We have three options for 100G backplane
  - define NRZ PHY and corresponding “improved” medium only
  - define PAM4 PHY and corresponding medium (based upon 802.3ba) only
  - define NRZ PHY/medium and PAM4 PHY/medium
- Based on presentations in next few meetings the task force must converge to one of the three options above.

What if we standardize a single PHY?

- NRZ PHY only
  - Enables efficient 100G transmission over “improved” backplanes.
  - Strands installed base of backplanes.
    - An alternate solution will need to be defined outside the scope of IEEE to address a real market segment.
- PAM4 PHY only
  - Enables robust transmission over installed base of backplanes.
  - Forces less optimal PHY for use on “improved” backplanes.
- Either way we are making a significant compromise.

PHY Coverage

- Easy channels.
  - Use NRZ with FEC optionally bypassed. Low latency. Low power.
- Medium channels (e.g., up to worst case “improved”)
  - Use NRZ with FEC. Lower power.
  - Use PAM4 with FEC optionally bypassed. Lower latency.
  - Trade-off between power and latency.
- Difficult channels (e.g., up to worst case installed base)
  - Use PAM4 with FEC.



NRZ/PAM4 Pro/Con

	Pro	Con
NRZ	Optimal for “improved” backplanes. Same coding as is expected in the module/cable interface.	Not compatible with installed based. Mixed signal data path more challenging for test, validation, yield, and portability.
PAM4	Compatible with installed base and “improved” backplanes. Lower symbol rate makes it compatible with lower bandwidth installed base and enables DSP. DSP improves performance, robustness, yield, testing, and portability.	Not optimal for “improved” backplanes. Signal processing for installed base backplanes results in larger area and higher power consumption.

NRZ

- optimal for “improved backplanes
  - backplane channel set to be compatible with practical implementation
- higher symbol rate
  - not compatible with installed based
  - too fast for power efficient DSP
- same coding as is expected for 4x25G module/cable interface
- Complex mixed signal data path
  - challenging to repeat from design-design, process-process
  - mixed signal testing of complex path
  - lower yield
  - longer validation cycle
  - hard to squeeze out more performance, if required
  - tracking of temperature, operation over process, are challenging for mixed signal

PAM4

- Lower symbol rate
  - compatible with lower bandwidth installed base
  - amenable to DSP receiver
  - compatible with standard, high volume processes
- DSP receiver
  - more digital, less mixed signal
  - leverage shrinking geometries
  - more repeatable from design-design, process-process
  - mixed signal testing limited to front end; ADC testing is more straight forward than for DFE
  - complex filtering in DSP testable using digital techniques
  - higher yield (particularly at package level); use DSP
  - adapt better to temperature variation on far end transmitter and local analog front end

802.3bj Work Plan

- How do we define two PHY types?
- Define two mediums.
  - One medium with limits similar to those defined for 802.3ap and 802.3ba to address the installed base.
  - One medium with limits consistent with “improved” backplanes.
- Define one PHY for each medium
  - PAM4 or similar coding with enhanced signal processing to leverage bandwidth inherent in 802.3ap/ba backplanes.
  - NRZ coding with mixed signal processing for efficient operation on “improved” backplanes.

Proposal for PHY reconciliation

- Link PHY type may be determined through Clause 73 auto-negotiation
  - Include separate advertisement bits for 100G NRZ and PAM4 PHY types in AN advertisement.
  - If both link partners advertise PAM4 then proceed using PAM4.
  - If both link partners advertise NRZ and one or both do not advertise PAM4, then proceed using NRZ.
- Note that a device may implement
  - 100G NRZ only
  - 100G PAM4 only
  - both 100G NRZ and 100G PAM4

Summary

- Trade-off between backplane and PHY performance differs between vendors, systems, and applications.
- One end of the spectrum is stranded if we define a single PHY/medium type.
- To address the full range we need to consider two PHY/medium types.
  - NRZ for “improved” backplanes.
  - PAM4 for installed base backplanes.
- The two PHY types can co-exist.

Thank you!