# A Gigabit "Subset PHY" Approach for 10GBASE-T Energy Efficient Ethernet

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# Subset PHY Review

- 802.3 defines a set of distinct copper PHYs
  - Each PHY defined for single speed operation
  - Ability to rapidly switch between PHYs not considered
- Alternative is to define a set of line codes specifically designed to support rapid switching between data rates
  - Highest data rate "parent" PHY is a standard $n$BASE-T PHY
  - Lower data rate subset PHYs designed to retain information necessary for rapid switching back to highest data rate
    - Synchronization, equalizer coefficients, canceller coefficients, frame alignment
- Line code for lower data rate is a simple subset of the higher data rate (standard) mode
  - Subset PHY implemented by simply turning off elements of higher data rate standard parent PHY

# Potential Subset Modes for 10GBASE-T

1. **Turn off** 3 of the four channels
   - 800Msps symbol rate remains the same for the active channel
     - Equalizer and echo canceller continue to adapt for active channel
   - Synchronization and master/slave loop timing retained
   - First step in reducing rate to 1Gbps
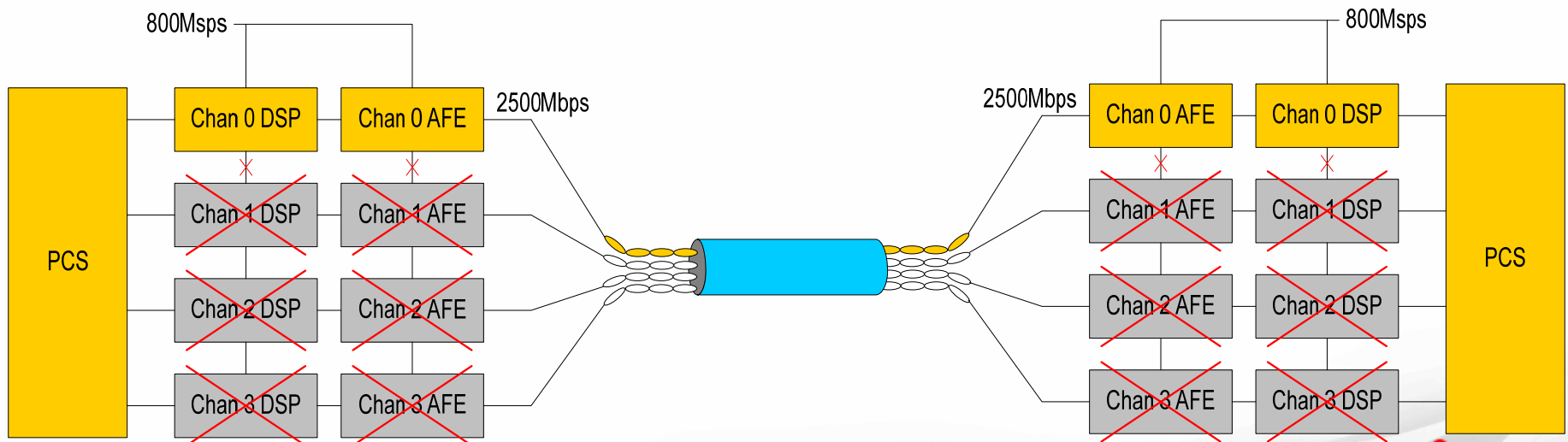
# Potential Subset Modes for 10GBASE-T

2. **[Turn off]** echo cancellers and hybrids (duplex to simplex)

   – Next canceller is usually less complex
   – Better dynamic range on ADC (no echo)
   – Does not change the number of active transmitters or receivers
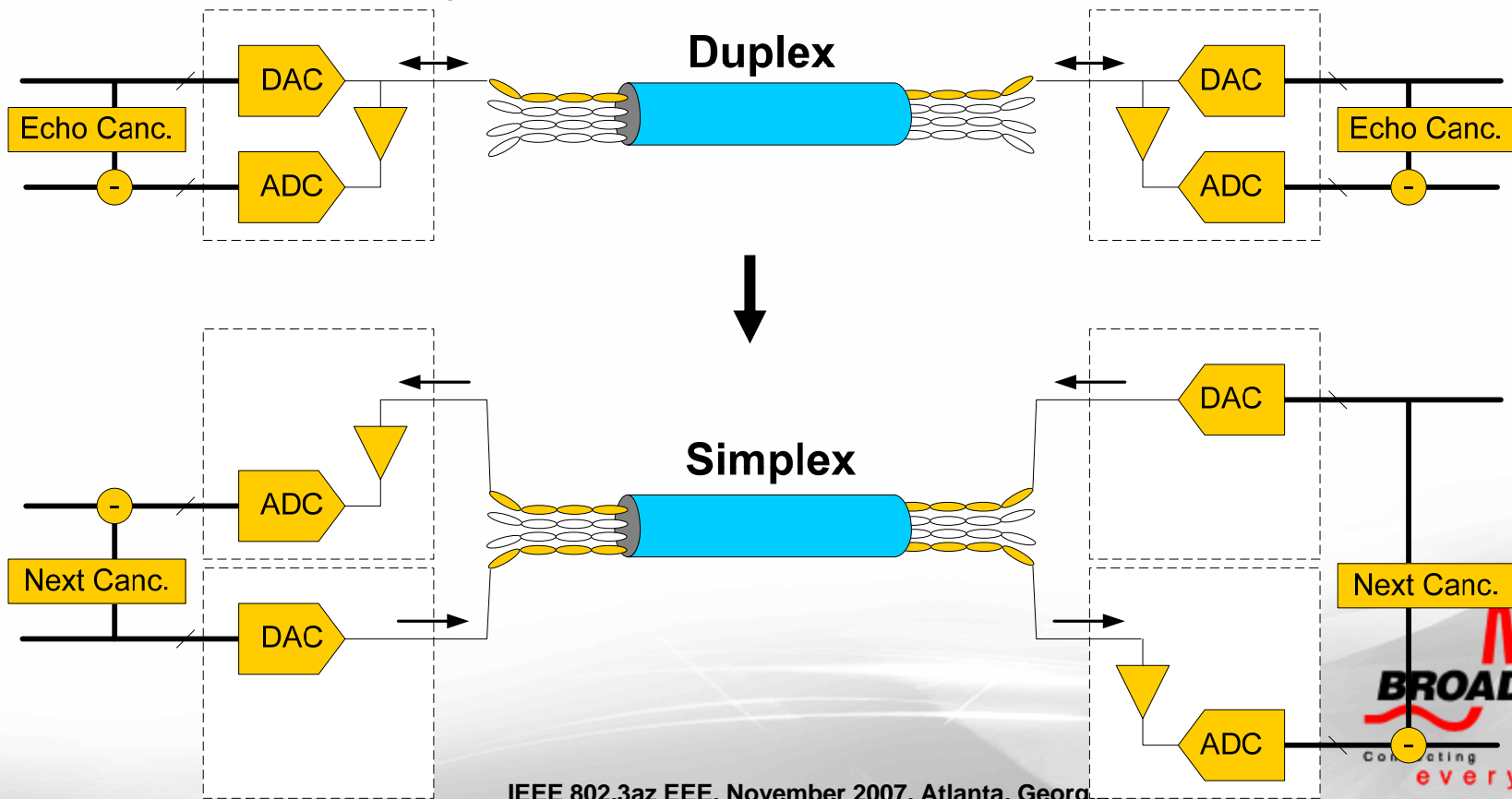
# Potential Subset Modes for 10GBASE-T

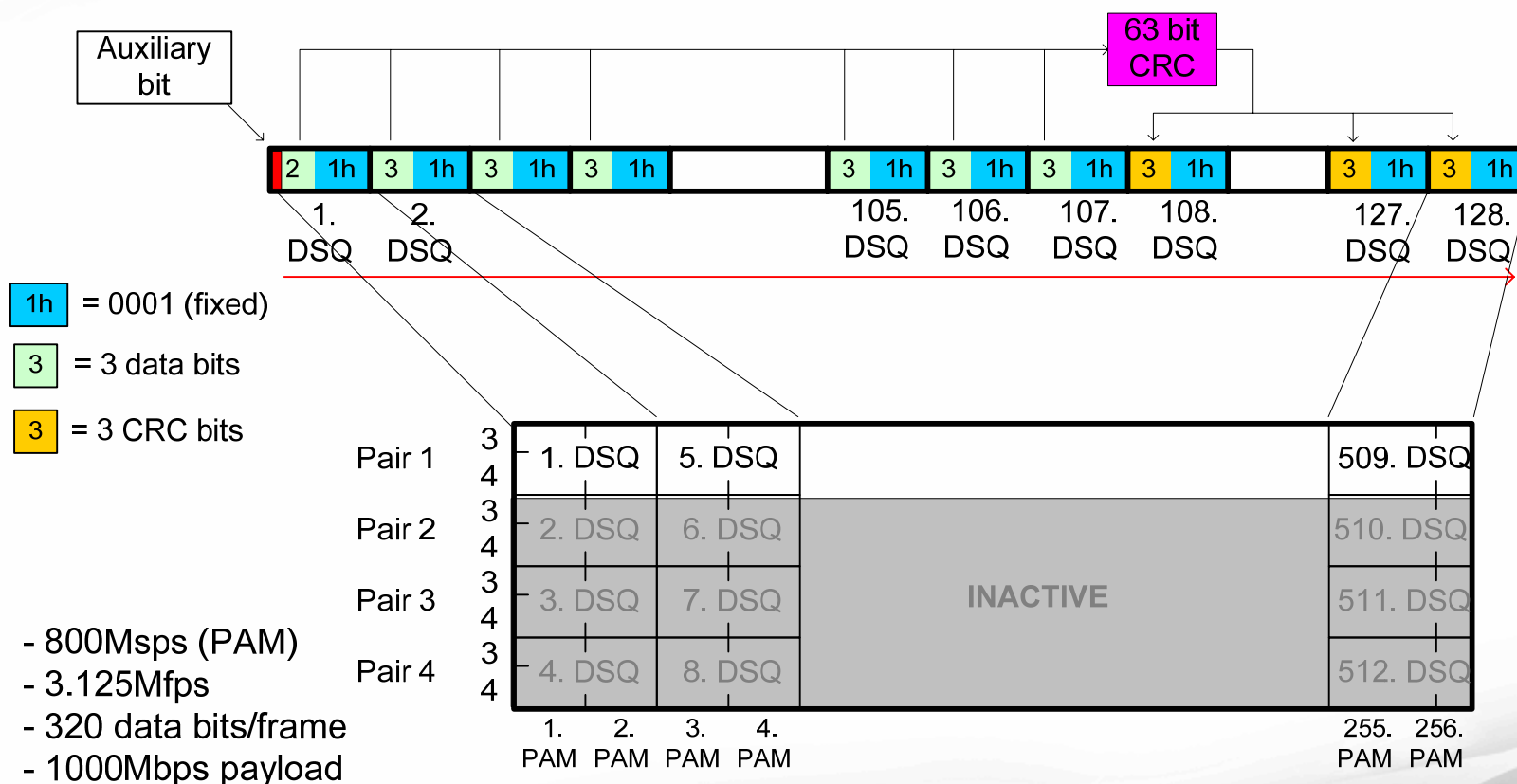3. **Turn off** extra constellation points

- 8DSQ symbols formed by 10GBASE-T 128DSQ subset partitions
- Turn off LDPC encoder and decoder (big power savings)
- Data protected by subset partition gain
  - Same BER as full rate 10GBASE-T
- Enough "spare" bits to add 63b CRC for error detection $(P_{undet} < \sim 10^{-19} \cdot P_{err})$

**10GBASE-T 128DSQ Constellation**

**1Gbps Subset PHY 8DSQ Constellation**
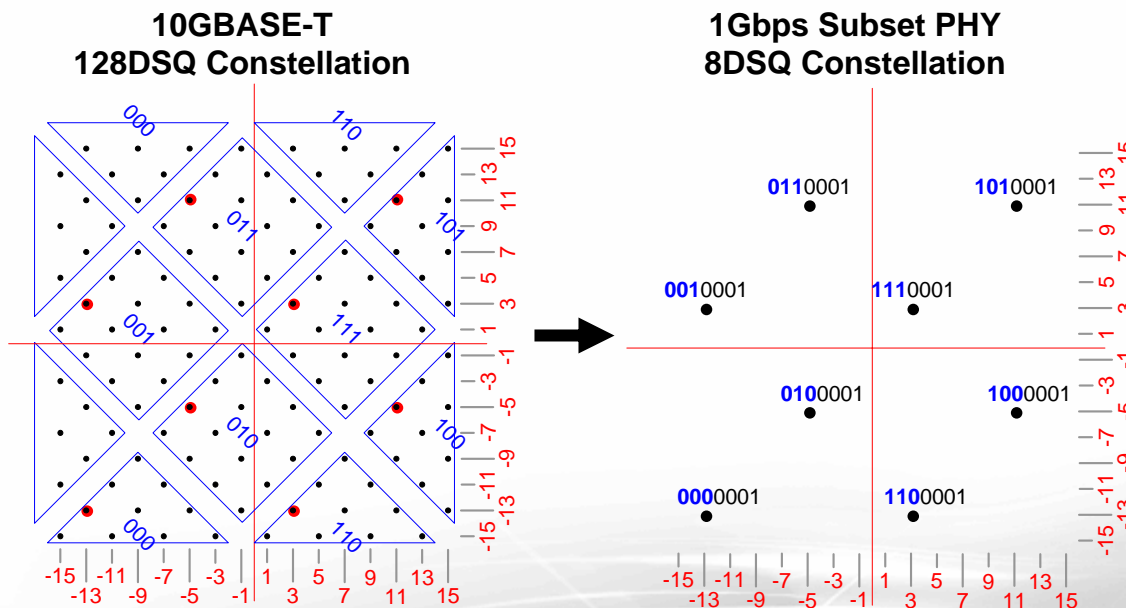
- 8 Subsets (uncoded)
- 16 points per subset (coded)

**IEEE 802.3az EEE, November 2007, Atlanta, Georgia**

# 1Gbps Subset PHY Framing/mapping

- Simple modification to 10GBASE-T Clause 55 framing:



- 800Msps (PAM)
- 3.125Mfps
- 320 data bits/frame
- 1000Mbps payload

# Updating Inactive Channels

- Zimmerman_01_0307.pdf presents measurements indicating:
  - The state of a 10GBASE-T PHY need only be updated every 3~5 minutes
  - Updates should require less than 20ms

- Inactive channels and cancellers not being used for anything else
  - Available to be used for refresh operation
  - Does not impact data transfer, link maintained
  - Does not require switching back to higher speed

- Inactive channels can be updated by turning them on for 20ms every 3 minutes
  - Transmit idles
  - Very low duty cycle makes update power negligible

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# An Additional OOB Channel

- Subset PHY approach provides an additional OOB channel that is independent of the packet transfer
  - One use could be to synchronize updates of inactive channels

- 10GBASE-T Clause 55 reserves one bit per LDPC frame for use as an OOB communication channel
  - "The use of this bit for vendor-specific communication is outside the scope of this document. For the purposes of this standard it is ignored by the link partner."

- The 10GBASE-T auxiliary channel allows for 3.125Mbps full duplex communication
  - Does not interfere with data traffic

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# 1G Subset PHY Power Estimate

- Analog
  - 3 of 4 ADCs and DACs powered down
  - All 4 hybrids powered down
  - Estimate 85% power saving

- Digital
  - All 4 echo cancellers powered down
  - 11 of 12 NEXT cancellers powered down
  - All 12 FEXT cancellers powered down
  - 3 of 4 equalization filters powered down
  - 3 of 4 Precoder filters powered down
  - LDPC encoder and decoder powered down
  - Estimate >85% power savings

- Estimate ~85% power reduction in 1G subset PHY mode
  - About 7x power reduction

# Practical Considerations for Switching Between Standard PHY Types

- 10/100/1000BASE-T and 10GBASE-T must share the same MDI
  - Likely to have one AFE for all speeds, could have separate digital
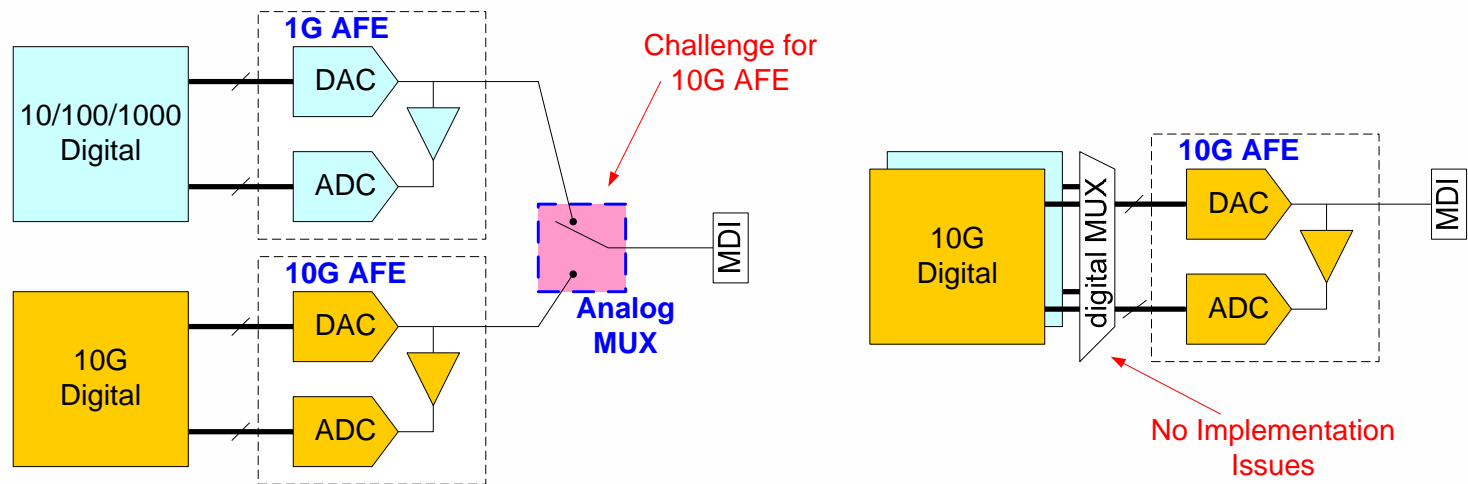
Option 1:  Switch at AFE Output

Option 2:  Switch at AFE Input

- AFE must be sized to support 10GBASE-T
  - Number of bits ADC/DAC, PGA, linearity, jitter, etc. set by 10G spec

- 10/100/1000BASE-T may not be the lowest power way to implement 10/100/1000 Mbps data rates within a 10GBASE-T PHY

# Summary

- Line code for lower data rate is a simple subset of the higher data rate (standard) mode
    - Subset PHY implemented by simply turning off elements of higher data rate standard parent PHY
    - A subset PHY is designed specifically to permit rapid speed change

- Subset PHY approach enables PHY-level synchronization
    - Further reduces time to switch over packet based synchronization

- Subset PHY maintains state of "parent" PHY
    - Echo, NEXT, FEXT, equalizer, and sample clock are all kept current without requiring a speed change

- Micro-second order of magnitude data rate transition time technically feasible
    - ~7x or greater power reduction

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