

# **EPoC Study Group**

## **Considerations and Recommendations for EPoC Error Performance**

**15 May 2012**

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# Overview

- Different Media, Different Error Rates?
- *Not* So Different Error Rates!
- Different *Type* of Error Rate Requirements
- Are Current DOCSIS Error Rates Workable for EPoC?
- Can Coax PHY Provide 10 Gigabit Ethernet Error Rates?
  - Yes, **but**...
- Suggestions for Coax PHY Error Rate EPoC Project Objectives
- Conclusion

# Different Media, Different Error Rates?

- EPoC Study Group priority is
  - maintain EPON MAC, and higher layer protocols, and
  - develop 802.3 PHY for coax segment
- IEEE 802.3 10 GigE error rate requirement:  
**Bit Error Rate**  $\leq 10^{-12}$
- HFC error rate requirements (typical):
  - Downstream (DOCSIS): **Bit Error Rate**  $\leq 10^{-8}$  or  
**Codeword Error Rate**  $\leq 9 \times 10^{-7}$  ( $\sim 10^{-6}$ )
  - Upstream (recent requirements examples):
    - US: **Codeword Error Rate**  $\leq 10^{-4}$  (for long packets)  
(*and even higher error rate requirements in some cases*)
    - China MSO position, March 2012 IEEE 802.3, NGHFC Key Requirements:  
**Packet Error Rate**  $\leq 10^{-4}$

# Different Media, Different Error Rates?

- These Cable Codeword Error Rates translate into:
  - Cable Downstream – **Bit Error Rate**  $\leq 10^{-8}$  (solid estimate)
  - Cable Upstream – **Bit Error Rate**  $\leq 10^{-6}$  (rough estimate)

## Different Media, Different Error Rates?

- Ethernet and Cable error rate requirements differ in both
  - a) type of error requirement and
  - b) actual error rate
- Type of requirement:
  - Cable – Codeword Error Rate
  - Ethernet – Bit Error Rate
- Error rate comparison:
  - Cable Downstream – **Bit Error Rate**  $\leq 10^{-8}$
  - 10 Gigabit Ethernet – **Bit Error Rate**  $\leq 10^{-12}$

10 GigE error rate requirement is about four orders of magnitude more demanding than Downstream Cable

Downstream Cable error rate requirement is about two orders of magnitude more demanding than Upstream Cable

## Different Media, Different Error Rates?

- Cable's HFC error rates are higher than 10 GigE error rates!
  - ~4 orders of magnitude higher downstream
  - ~6 orders of magnitude higher upstream

But Hold On!

- Ethernet 10BaseT error rate:  
Bit Error Rate  $\leq 10^{-8}$

AND

- Ethernet First Mile (EFM) error rate:  
Bit Error Rate  $\leq 10^{-7}$

## ▶ Not So Different Error Rates!

Therefore

- Cable's HFC error rates are comparable to some existing Ethernet error rates!
  - Cable downstream error rate comparable to 10BaseT
    - Lower error rate than EFM
  - Cable upstream error rate within order magnitude of EFM

Different Universes Regarding Error Rates?

**Not So Much!**

# Different *Type* of Error Rate Requirements

- In Cable ---
  - It is more meaningful to impose Codeword Error Rate requirements (or Packet Error Rate requirements) than Bit Error Rate requirements
- Most modern communication systems use some form of Forward Error Control (FEC) coding
  - Generates correlated bit errors
  - Results in rate of error events which is NOT directly related to BER
    - Error event rate may be 1/10x (or less) versus “assumption” from BER
    - *Codeword Error Rate is much more directly related to error event rate*
- Downstream: one figure of merit is error event rate for video
  - Rate of occurrence of noticeable error events for viewer
- Upstream is burst-transmission based and packet-based
  - Does message make it or not? Entire packets sometimes lost!
- Codeword Error Rate more closely matches system need
  - *Packet Error Rate is even better metric*

# Different *Type* of Error Rate Requirements

- Why not Codeword Error Rate (or Packet Error Rate)?
  - BER approach has history and “feel”
  - Relating Codeword Error Rate or Packet Error Rate to system need (higher level requirement) may not be straightforward (neither is BER)
    - e.g., Different sized packets in mix
    - Setting Packet Error Rate requirement quickly degenerates into discussion of different error rate requirements for different services
      - Debate ensues about efficacy of moving away from BER at all
      - Requires systematic approach and discipline
    - Codeword Error Rate is related to FEC parameters
      - Thus cannot allocate a “Codeword Error Rate” and THEN define FEC
  - BER easier to test (not really true anymore)
- Why not BER?
  - Even further removed from the real system need than CER or PER
    - Packets failing CRC are thrown out anyway; **individual bit errors are irrelevant in Ethernet today**, so BER is irrelevant and even misleading
  - Upstream cable is burst transmission and **entire packets can be lost**
    - Could **distort BER measurement** and make it extremely misleading

# Different *Type* of Error Rate Requirements

- Why not Codeword Error Rate (or Packet Error Rate)?  
*Continued*

There is precedent for “Frame Error Rate” within IEEE 802.3

- Even IEEE 802.3 has adopted “Frame Error Rate” as the error rate metric in a recent standard
- From IEEE 802.3an-2006:  
“This specification shall be satisfied by a frame error rate less than ...”

## 55.5.4.1 Receiver differential input signals

Differential signals received at the MDI that were transmitted from a remote transmitter within the specifications of 55.5.3 and have passed through a link specified in 55.7 are received with a BER less than  $10^{-12}$  and sent to the PCS after link reset completion. This specification shall be satisfied by a frame error ratio less than  $9.6 \times 10^{-9}$  for 800 octet frames with minimum IPG or greater than 799 octet IPG.

## Different *Type* of Error Rate Requirements

- BER versus CER or PER boils down to: adopting a merited modern approach, or holding on to outmoded approach
- From Cable perspective:

*Packet Error Rate is now the best metric for specifying system requirements at beginning of project*

- Understanding we are an IEEE 802.3 Study Group, we accept (in spirit of progress and compromise) retaining BER as metric (if IEEE 802.3 insists!)
  - Lost upstream packets have to be handled appropriately in calculation
  - We present our error rate recommendations as “BER or PER,” similar to our DOCSIS approach for downstream
  - We accept that IEEE 802.3 will probably adopt a BER requirement and discard PER

# Are Current DOCSIS Error Rates Workable for EPoC?

Do services themselves require the low Ethernet error rates (e.g., 10 GigE) be imposed on PHY coax?

- Answer: NO, because residential and business services are currently adequately supported by HFC performance.
  - But future needs may dictate different result
  - This is an area where Task Group contributions may be provided
- DOCSIS currently supports a variety of service types:
  - File download/upload, constant bit rate service like voice, IP video streaming, P2P applications.
- Distributing the service *faster* (e.g., 10x) *does not mean* the *BER has to get 10x better* (lower)
- Distributing 10x more services does not mean each service has to have 1/10<sup>th</sup> the errors it had at 1x
- We can still ask: Do we need to do better?

# Can Coax PHY Provide 10 Gigabit Ethernet Error Rates?

CAN Coax provide  $10^{-12}$  BER?

- And if the answer is “YES,” then: **At what “cost”?**
- There are severe permanent penalties in the

*error rate/latency/throughput (or spectral efficiency)*

“triangle of critical performance” if error rate is pushed too low

Not to mention --- potential complexity penalty, too

- “Penalty”s for low BER are greater for non-AWGN channels
  - Cable coax channel model is not (yet) known as AWGN
  - Current Cable channel models in wide use are not AWGN

# Can Coax PHY Provide 10 Gigabit Ethernet Error Rates?

Answer: Coax CAN provide  $10^{-12}$  BER

- It isn't impossible... **but**
- Firstly, this will require best practices in plant design, installation, and maintenance --- OK!
- **AND THEN**, relatively **severe** penalty in bps/Hz, at minimum;
- perhaps latency penalty, too;
- For example, *taking a preliminary stab*, perhaps
  - 20% reduction in bps/Hz downstream
  - 50% reduction in bps/Hz upstream
- Can trade more latency for better bps/Hz, but latencies of existing Cable already relatively large
- Possibly much more complexity required, too

# Can Coax PHY Provide 10 Gigabit Ethernet Error Rates?

- Boils down to
  - Take relatively severe spectral efficiency penalty, and
  - Perhaps latency penalty,
  - Probably complexity penalty

in order to meet 10 Gigabit Ethernet error rate requirements.

- From Cable perspective --- don't push the rock up the hill!

# Suggestions for Coax PHY Error Rate EPoC Project Objectives

- Recommendation: Target Packet Error Rates for EPoC similar to today's Cable Codeword Error Rates
  - Means higher performance since packets likely longer than Cable's current codewords (but about the same BER)
  - Downstream Packet Error Rate  $\leq 10^{-6}$
  - Upstream Packet Error Rate  $\leq 10^{-4}$
  - Upstream Packet Error Rate  $\leq 10^{-6}$  (goal with minimal impairments?)
  - Goals for lower error rates (see Conclusion slide)
- For compromise with IEEE 802.3 history of using BER, provide comparable BER requirement
  - As in DOCSIS downstream with Codeword Error Rate requirement  
OR Bit Error Rate requirement
- Optional, lower upstream error rate requirement corresponding to lower impairments than current upstream
  - Perhaps corresponding to better plant, e.g., targeted to businesses
  - Perhaps corresponding to higher frequencies than today's upstream
  - Separate channel model

# Conclusion

- This contribution describes
  - Differences between current Cable and 10GE error rate requirements
  - Error rates of current Cable *are* similar to *some* Ethernet error rates
  - The difficulty and penalty of requiring, over coax, 10GE error rates
- Recommends targeting error rate requirements
  - Downstream Packet Error Rate  $\leq 10^{-6}$   
OR Downstream Bit Error Rate  $\leq 10^{-8}$   
with Task Group Goal of Downstream Bit Error Rate  $\leq 10^{-10}$
  - Upstream Packet Error Rate  $\leq 10^{-4}$   
OR Upstream Bit Error Rate  $\leq 10^{-6}$
  - As an Option, in minimally impaired upstream,  
Upstream Packet Error Rate  $\leq 10^{-6}$   
OR Upstream Bit Error Rate  $\leq 10^{-8}$   
with Task Group Goal of Upstream Bit Error Rate  $\leq 10^{-10}$
  - These recommended Bit Error Rate *requirements* are comparable to 10BaseT and Ethernet First Mile error rates

**Thank You**

**Broadcom and others**