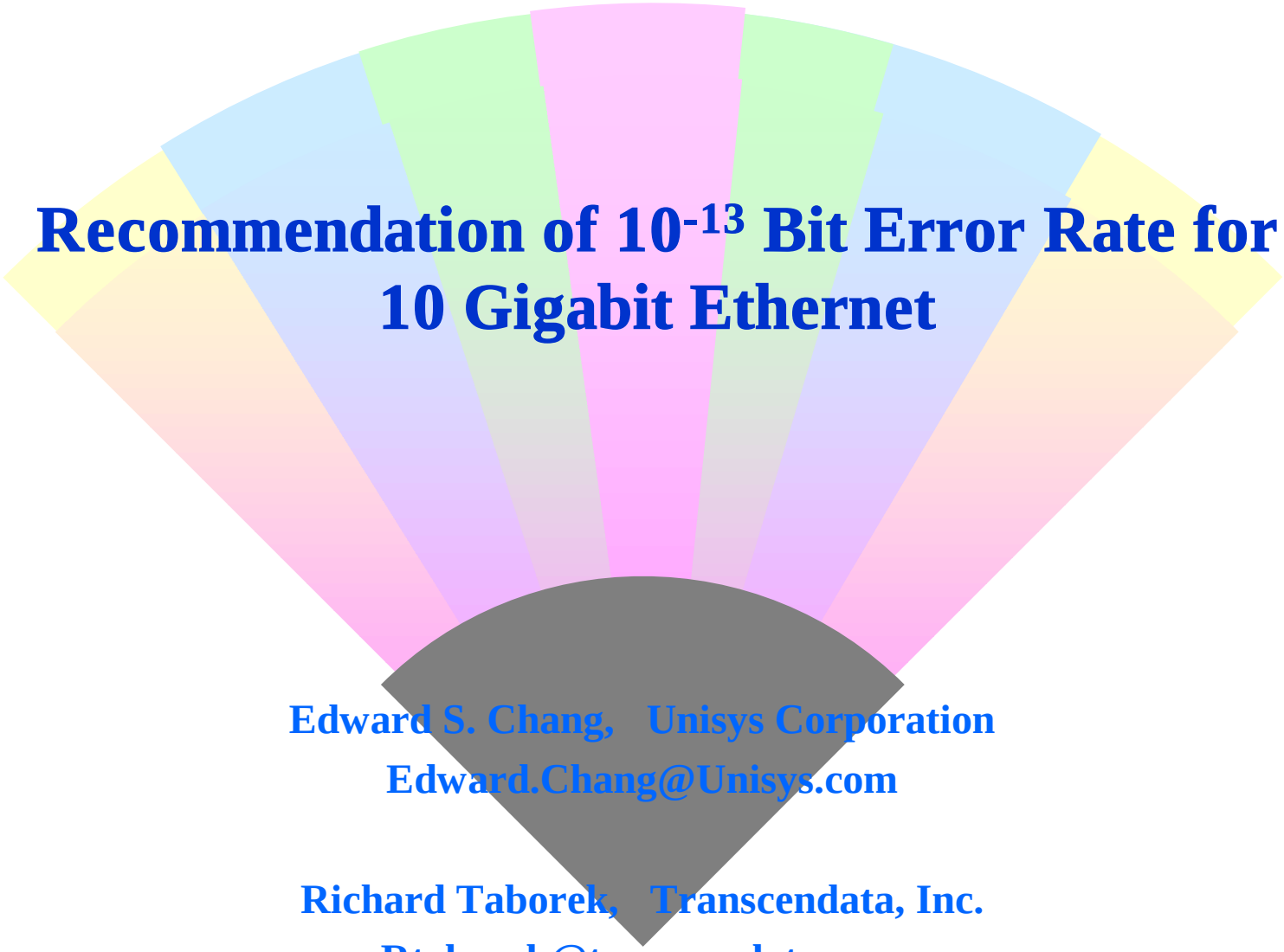
Recommendation of 10^{-13} Bit Error Rate for 10 Gigabit Ethernet



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Abstract

Recommendation of 10^{-13} BER for 10GbE

- BER -- Criteria for a Reliable and Cost-Effective Link
  - High Reliability and Low Cost demanded by competitive market
  - Optimum BER -- the guiding specification to achieve the goal
- BER Design Objective
  - Definition -- bit cell time = > DJ + RJ (at given BER)
  - Cost at a given RJ -- cost inversely proportional to BER
  - Design criteria -- reliable enough, but not over designed
  - Reliability objective -- meet the target throughput with negligible variation due to BER effects

Causes of Bit Errors
Recommendation of 10^{-13} BER for 10GbE

- Jitter -- components with excessive jitter
  - TJ = DJ + RJ (at a BER)
- Bandwidth -- insufficient link BW
  - Bit time => rms Sum (tT + tF + tR)
- Optical power -- improper power allocation
  - Pin > Pmin (receiver sensitivity)
- SNR -- poor signal to noise ratio
  - BER = f (Is, In)
- Base-line-wander -- poor coding scheme and circuit design
- RJ -- The Key Parameter Determine BER

Optimum BER Design Goal
Recommendation of 10^{-13} BER for 10GbE

- BER Design Goal -- Optimum Cost-performance
  - Extend Data Rate and Distance to the limit of a maximum acceptable BER
  - Maximize BER at given Data Rate and Distance
- Penalty of High BER
  - Throughput reduction -- retransmission of packets containing errors
  - More retransmissions per unit time at 10 GbE than GbE (at same BER)
  - Investment on 10 GbE wasted -- poor cost-performance
- BER improvement desirable and recommended for 10 GbE

Enterprise Throughput Ratio and BER

Recommendation of 10^{-13} BER for 10GbE

- **TCP --Assure Reliable Communication between Hosts**
  - Retransmit -- data damaged(BE), lost, out of order, time-out
  - High BER -- wasting more time in retransmitting

- **Throughput Ratio (R) of Actual and Error Free Transmission**

  R = T (actual)/T(error free)

  = 1 + BERxDRxTe…….. (1) See Appendix

  Te: elapse time for time out in seconds, DR: data rate

- **Throughput Ratio at BER 10^{-12} and 10^{-13}**
  - GbE, BER 10^{-12} -- equation (1): R = 1 + 0.001xTe (2)
  - 10 GbE, BER 10^{-12} -- equation (1): R = 1 + 0.01xTe (3)
  - 10 GbE, BER 10^{-13} -- equation (1): R = 1 + 0.001xTe (4)

Low BER Requirement

Recommendation of 10^{-13} BER for 10GbE

- BER 10^{-13} to Maintain Same Throughput as GbE
  - GbE throughput ratio -- R = 1 + 0.001xTe (2)
  - 10GbE throughput ratio -- R = 1 + 0.001xTe from (4)
- BER 10^{-13} to Maintain Cost-Effectiveness
  - Throughput ratio at BER 10^{-12} -- R = 1 + 0.01xTe from (3)
  - Throughput ratio at BER 10^{-13} -- R = 1 + 0.001xTe from (4)
  - As Te increases, throughput decreases -- require low BER
  - Assure investment in 10GbE is not wasted by low throughput

Appendix

Recommendation of 10^{-13} BER for 10GbE

For an Enterprise System, a FTP file transmitting time, Tt, required to transfer data from host A to host B can be expressed in equation (1).

Tt = Th1 + Tn1 + LxTd + Tr + Tn2 + Th2 + 10xNxP/DR…….. (1)

For the TCP protocol, acknowledgement time, Ta can be shown in equation (2)

Ta = Th1 + Tn1 + LxTd + Tr + Tn2 + Th2 + 10x46/DR ……..(2)

Where the propagation delays :

Th1= host A, Tn1 = NIC A, LxTd = transmission media, Tr = router/switch

Th2 = host B, Tn2 = NIC B, Nx = number of packets in a TCP window, P = packet size in bytes, DR = data rate

10x46/DR = acknowledge (ACK) data size

Therefore, the throughput ratio, R , of the actual transmission and error free transmission can be shown in equation (3).

R = [(Tt + Ta) + WER (Tt + Te)]/(Tt +Ta) ……..(3)

Where: WER = TCP widow error rate = 10NxP(BER).

Te = elapsed time for time out.

Appendix - continue

Recommendation of 10^{-13} BER for 10GbE

Simplify equation (3) to obtain equation (4)

$R = 1 + WER(Tt + Te)/(Tt + Ta)$ ……. (4)

For an Enterprise FTP data transfer, the window data size is much larger than ACK size, and the time out Te is much larger than Tt, therefore,

from equations (1) and (2), Tt>>Ta, and also, Te >> Tt to further simplify equation (4)

$R = 1 + WERxTe/Tt$ ……..(5)

Normally, a well designed Enterprise system does not cause congestion; therefore, the file transfer time is much larger the path delay. As a result, simplify equation (1) to obtain $Tt = 10xNxP/DR$

Substitute $Tt = 10NxP/DR$ and $WER = 10NxP(BER)$ to equation (5) to obtain equation (7)

$R = 1 + 10NxP(BER)xTe/(10xNP/DR)$

$= 1 + (BER)xDRxTe$ …….. (7)