COMMSCOPE®

Short Reach Power Saving Considerations for 10GBASE-T Applications

White Paper

May 2012

at work

Contents

List of Figures

1 General

In the current environment of saving power, especially in Data Centers (DC), there is much interest and discussion in understanding the power back-off and dynamic power saving features of 10GBASE-T implementations. This paper will discuss several topics related to powering options and power saving considerations for 10GBASE-T applications. The paper covers several implementation options available from different PHY designers, cabling system considerations, and recommendations for going forward. Cabling vendors have claimed reductions in PHY power are possible using "improved" cabling. This paper will examine the implementation issues of 10GBASE-T and the reality of such claims. Secondly, this paper will address the risks and consequences of using cabling with nonstandard insertion loss (IL) characteristics both in terms of power and interoperability.

2 How Cabling Considerations Impact 10GBASE-T Power Consumption

There are many questions and misconceptions about the effect that different cable constructions may or may not have on improving power savings. These include:

1. Shielding reduces power consumption
2. What is the effect of using 26 AWG cables instead of 24 AWG?
3. Ability of PHYs to sense cable characteristics and adjust their Digital Signal Processing (DSP) accordingly
4. Does power backoff on the transmitter lead to increased power in the receiver?
5. If IL is used to infer cabling length, does the use of non-24 AWG cables confuse the delay computation and compensation circuitry in PHYs?
6. Can the savings in one individual link be scaled to all the links in a cable bundle?

This section will first examine the basis of these claims, and then describe how they relate to cable values.

2.1 What is the basis for cabling vendors to claim PHY power reductions?

Several cabling vendors claim their cabling (generally shielded products) can reduce PHY power by improving the PHYs signal to noise ratio, or SNR. There are fundamentally two assertions made:

1) That the Power Back Off (PBO) reduction in transmit power mandated by the 10GBASE-T standard will be positively affected, allowing for a greater reduction in transmit power, and hence a power savings at the transmitter, and
2) An assertion that PHYs will disable signal processing at the receiver when the SNR is sufficiently high. This technique is known in PHY design as "dynamic power scaling", and is referenced in several 10GBASE-T PHY vendors' literature.

While there is some truth in this, the power savings claims are exaggerated and the causes of the power savings are not as advertised. To understand this we must consider the details of these power saving modes.

2.2 What is Power Back Off, and how does it relate to cabling quality?

PBO is a technique mandated by the IEEE 10GBASE-T standard (IEEE Std. 802.3an-2006, now clause 55 of IEEE Std. 802.3), for managing alien far-end crosstalk levels in a network. PBO levels do not vary based on cable type. Rather, the standard mandates that they be related to the received signal power, which, in turn relates them to the cable IL and the transmitted power spectrum of the PHY presenting the back off. Since the PHY's full transmit power is required to be within +/– 1.0dB of the nominal value by the 10GBASE-T standard, the result is that the amount of power back off is largely a function of the cable IL.

As an interference management technique meant to combat alien FEXT, it was important that reductions in transmit power of a disturbing line be related to the link segment length since alien FEXT coupling is proportional to the coupling length and the IL of both the coupling links under consideration. PBO therefore appears to be related to length, but, in fact, is driven by IL.

2.3 The standard only specifies minimum power back off, why don't PHYs save power by further reducing transmit power below the minimum when good quality cabling is used?

The designers of the 10GBASE-T standard specifically limited the range of PBO and warned against excessively relating it to receiver SNR. Cabling vendors have asserted that PHY vendors might optimize their transmit power based on such an SNR metric, but this is something that was specifically avoided by the standards' authors. This was to ensure link stability, because power back off settings can only be changed at link start up. PHY designers may make minor adjustments to PBO during phases of startup, but the larger adjustments necessary to save significant power are actually discouraged. Additionally, the two PHYs in a linked pair are required to adjust their PBO settings to within 4 dB of each other's in order not to negatively impact each other's crosstalk and echo cancellation requirements. This has the effect of limiting the amount of PBO optimization that may be done while maintaining interoperability.

Systems engineers will recognize that the first few cables in a bundle will experience abnormally low interference on startup, and overly trimming their PBO or signal processing based on this high SNR will cause their links to fail as other links are brought up. When they restart they, in turn, will come up at higher levels, introducing more interference into the other links. If they were trimmed to take advantage of the additional SNR, they, in turn, would fail. Avoiding this kind of cascading failure is a primary reason PBO was based on IL, not SNR. The result is that cable qualities other than the IL have little effect on power back off settings.

2.4 OK, so power back off depends on IL. What about other power saving means, such as Energy Efficient Ethernet, and Dynamic Power Scaling?

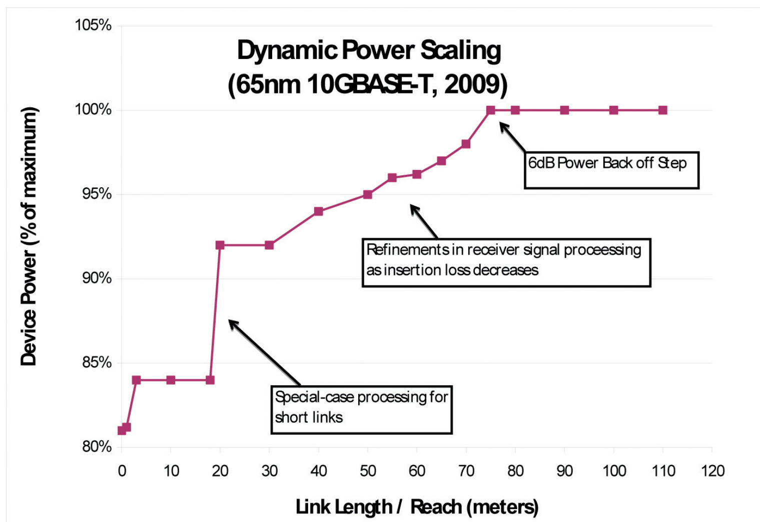
Many PHY vendors implement energy efficient techniques to scale PHY power consumption based on operating characteristics. There are two types of these: (1) Energy Efficient Ethernet, and (2) Dynamic Power Scaling.

Energy Efficient Ethernet (EEE), or IEEE Std. 802.3az, is unrelated to cabling parameters. EEE varies the activity of the PHY based on the traffic carried over the link. Newer equipment using this standard will exhibit energy savings independent of the cabling characteristics. Energy Efficient Ethernet is further described in section 2.7.

The second type of energy efficient optimization done by PHY vendors, Dynamic Power Scaling, involves optimizing which portions of the PHY signal processing and coding circuitry are active on a given link. Cabling quality can affect which portions of the circuitry are used more extensively. The saving is, however, primarily related to IL & cable length. Figure 1 shows an example of dynamic power scaling of a 65nm PHY in 2009. This example should be used for the qualitative effect only, since the actual power savings has reduced as the overall PHY's power has reduced in the 40nm generation.

Note also that dynamic power scaling is unrelated to the PHY's interface to the MAC, which takes an increasingly large percentage of the PHY power as overall power decreases. Dynamic power scaling goes beyond PBO by not only adjusting transmit power, but also adjusting receiver signal processing blocks. However, these adjustments are also generally fixed at startup, even though they are not specified by the standard, allowing only minor adjustments if the link SNR changes. Because systems and PHY vendors value the reliability of the link first, conservative assumptions about the noise environment must be made in setting the receiver dynamic power scaling parameters. The result of this is that like PBO, the majority of savings in Dynamic Power Scaling systems are related to the internal parameters of the link, and not the alien crosstalk, which can vary greatly as additional links are brought up.

Figure 1: Example of 10GBASE-T device power vs. link length using Dynamic Power Scaling



As Figure 1 shows, the dynamic power scaling is, like PBO, primarily related to the length or IL of the link, not the other cable qualities. Link equalization, in particular while apparently related to length, is more intricately tied to the link's delay and IL characteristics. This will generally track with the IL and length for standards-based cabling. FEXT cancellation and decoding savings also used in dynamic power scaling may be varied slightly with cable crosstalk characteristics, but these are minor effects and generally contribute to power savings only at a small fraction of a watt.

2.5 OK, so internal crosstalk does not greatly affect PHY power consumption. Is it cable length, delay, or IL that matters more?

For power back off savings, there is no question, the standard clearly points to the cable's IL as the controlling parameter. For dynamic power savings, it is a balance of these parameters. Because PHY vendors have designed their equalization, crosstalk cancellation, and power savings techniques with standards-based cabling in mind, it is important to use cabling that adheres to all of these aspects of the standard. For example, using low-cost cabling of a thinner wire gauge would cause reference 100 meter links to be out of specification with regards to IL, and would cause shorter links to have insertion losses and some equalization characteristics more like longer links than like links of their actual length. Because the delay on these lines would still be related to their physical length, settings for echo and crosstalk canceller lengths would generally not agree with those for power back off and equalizer lengths. The result would likely be more power consumed, and could create problems with PHY interoperability on the nonstandard cabling.

2.6 Can PHYs sense cable characteristics and adjust accordingly?

PHYs do not have the ability to sense whether the signal to noise environment is due to a transient quiet condition that may go away as noise sources become active (e.g., more links are turned up), or whether they are due to parameters of the cabling installation itself. As a result, they tend to adjust primarily to the internal characteristics of the cabling, particularly the IL, for adjusting transmit power and receiver signal processing. Reliable links demand that 10GBASE-T PHYs do not attempt to over-optimize based on received SNR at startup. Standards-compliant cabling systems share similar enough IL characteristics, that at the same physical length, there is little power advantage of one cabling system to another. <u>However, when standards-compliant cabling is used, an installation may save power by leveraging the fact that PHY vendors have relied on the relationships of delay, IL, crosstalk and length in such cabling to come up with robust, energy efficient power settings</u>.

2.7 Are there more improvements coming relative to power savings?

Power consumption has become a major issue, especially in data centers. IEEE has already published the IEEE 802.3az EEE standard using auto-negotiation and Wake on LAN (WOL) to further reduce power consumption. These technologies are now being implemented by PHY vendors in their new fourth generation products and should improve power savings compared to first, second, and third, generation 10GBASE-T PHYs.

By upgrading to use Energy Efficient Ethernet (IEEE Std. 802.3az) in conjunction with 10GBASE-T, a network can not only achieve higher peak performance, but can save energy. PHYs using IEEE Std. 802.3az are most efficient when they are used on lightly loaded (10-20% active) links. Using 10GBASE-T on lightly loaded links will allow the transceivers to enter a quiet or "low power idle" state when there is no traffic to send. In this state, much of the transmitter and receiver signal processing can be powered down, allowing a reduction in average power consumed. Figure 2 and Figure 3 show the large number of blocks that might be powered down when in the active idle state. Because the time spent in the low power idle state determines the power reduction, EEE can allow equipment to save power when it is used to replace heavily loaded 1000BASE-T ports with an EEE-enabled 10GBASE-T link. Installing 10GBASE-T capable cabling would enable this power saving application. <u>Since EEE energy savings are related to equipment capabilities and traffic utilization relative to the link speed, having cabling capable of supporting the maximum possible BASE-T link speed is the prudent first step in an energy efficient upgrade</u>.

Figure 2: Illustration of various DSP elements in a 10GBASE-T transceiver in their normal state

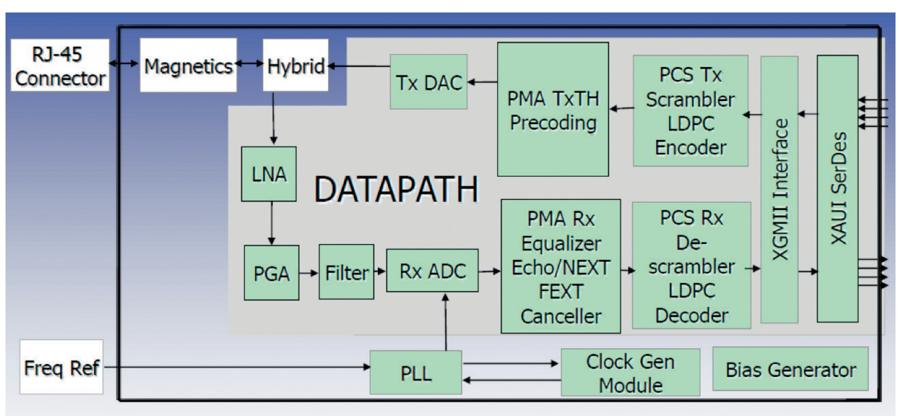
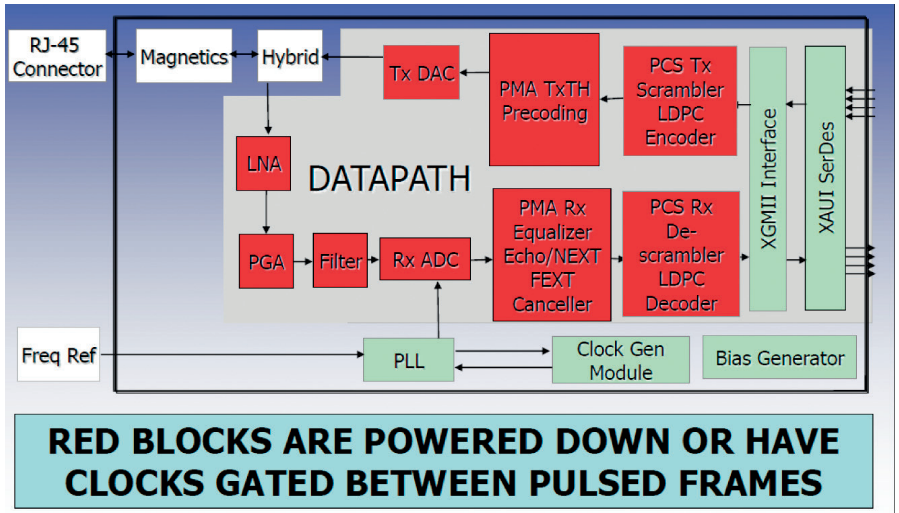


Figure 3: Illustration of 10GBASE-T DSP elements powered down during the EEE active idle state



2.8 How can I use standards-based cabling and 10GBASE-T to save power?

One way to save power, described earlier, is by replacing heavily-loaded 1000BASE-T links by lightly loaded 10GBASE-T links through energy efficient Ethernet. In this case, you would replace 2 to 5 loaded 1000BASE-T links with a single 10GBASE-T link, and not replace in a 10:1 ratio, since the objective is to create lightly loaded 10GBASE-T links and maximize the EEE active-idle time.

Additionally, use of dynamic power savings PHYs on a standards-based cable plant can have substantial impact on power consumption of the 10GBASE-T PHYs when looking at a large number of links. Because the bulk of the links in any installation are short, dynamic power scaling allows the average power consumption to reflect the consumption of the sub-50m links which dominate most installations.

2.9 Effect of using 26 AWG cables

Some vendors offer thin, inexpensive cables using 26 AWG copper, and exhibiting nonstandard IL. These cables have a higher IL than standard 24 AWG cables and will effectively trigger power back-off at different lengths than those shown in IEEE 10GBASE-T. This has the effect of decreasing the power back off settings requested on the link. The result may be excessive alien FEXT interference into adjacent links as well as the network in general, and will also include excess power consumption of the PHYs. Additionally, this may compromise the ability of the equipment to scale and compensate for delay characteristics of the cable.

3 Recommendations

It is important for end-users, consultants, designers, and system integrators to carefully evaluate short reach power saving considerations for 10GBASE-T to make wise choices in both equipment and cabling including:

1. Discuss short reach power savings features with PHY vendors and equipment vendors
2. Deploy cabling that conforms to ISO 11801 (including its amendments) and TIA-568-C.2 standards
3. Understand that power savings gains are not linear with length and tend to taper off after about 6 dB of insertion loss (IL) reduction
4. Look to replace heavily loaded 1000BASE-T links with lightly loaded 10GBASE-T links using Energy Efficient Ethernet (802.3az) rather than waiting for 10:1 consolidation.

The following points provide recommendations for improving the power savings of telecommunications cabling and 10GBASE-T equipment.

1. Use of shorter lengths between the transmitter and receiver will save power.
2. Use of shielded cables instead of unshielded cables will not result in any significant power savings
3. Use of longer segments of 26 AWG cables instead of 24 AWG cables is not recommended since it will reduce signal strength and potentially confuse delay compensation mechanisms in PHYs.

4 References

1. IEEE 802.3an Physical Layer and Management Parameters for 10 Gb/s Operation, Type 10GBASE-T

2. Ethernet Technology Summit – 10GBASE-T, the data center, and energy efficiency – George A. Zimmerman, Ph.D