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Planning for 10Gbps Ethernet over UTP

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Planning a copper cabling plant to support 10Gbps transmission is complicated today by the absence of ratified standards. There are, however, some questions you can ask that can help you navigate promises and claims in the market place and, ultimately, help you select the proper infrastructure to support future 10Gbps UTP applications.

Do you really need a cabling plant that can support 10Gbps Ethernet over UTP?

Historically speaking, cabling installed has always led the primary data rate. For example, over 90% of switch port sales in 1995 were for the 10Mbps Ethernet protocol. Yet in that same year, the primary UTP cabling installed was the 100Mbps Category 5, accounting for nearly 70% of UTP installed market share.

Similarly in 2001, about 70% of switch port sales were for 100Mbps. In the same year, Category 5e and Category 6, which both support 1000Mbps, accounted for over 80% of UTP cabling installed.

Of course, the next logical step in the data rate is another ten-fold increase to 10Gbps. With 10Gbps copper transceivers in development today and expected to market in 2006, the cabling plant must be able to handle the new protocol.

Can Category 6 cabling support 10Gbps Ethernet over UTP?

Actually, Category 6 cabling can support 10Gbps transmission—but only to 55 meters, per TIA TR42.7, Cat 6–TSB155. However, this is a costly proposition. The added construction costs for more telecom rooms to accommodate 55 meters (vs. the standard 100 meters) are nominal compared to the added costs of purchasing additional Ethernet switches and other active equipment for each additional telecom room to support data, VoIP or other applications.

What draft standards are important?

Clearly, a 10Gbps UTP cabling solution should support the full 100 meters. From a standards perspective, TIA TR42.7, Cat A6-568 B.2 Addendum 10 is the current (May 2005) view to support 10Gbps transmission over UTP at 100 meters. Look for compliance with this standard as you shop for a solution. The draft standards also require full interoperability and backwards compatibility.

What about shielded solutions?

Space, time and cost constraints were the drivers that led to the development of UTP cabling in lieu of shielded twisted pair (STP) solutions. Those reasons are still prevalent today. Still there are manufacturers that do not yet have a UTP solution and are promoting STP shielded solutions for 10Gbps transmission over copper.

However, shielded cabling typically requires more space in racks, cabinets, and raceways. Furthermore, grounding and bonding is a concern for shielded cable installations. Time to train and whether or not to ground at the station and the closet varies geographically and by whom you ask. Shielded cable construction will continue to be more costly than UTP cable construction, as well as more expensive to install. In fact, a recent ADC study concluded that an STP network would typically cost three times more than a UTP network.

Without TIA/EIA standards in place, what are good decision criteria for selecting a 10Gbps solution for UTP?

The cabling industry—TIA/EIA—does not drive the electrical parameters needed to run transmission protocols. It is the IEEE that develops proposed protocols, understands what is needed from an electrical perspective, and then gives TIA/EIA responsibility for developing measurable parameters for the cable and connectors.

When in doubt, follow the IEEE lead.

The IEEE 802.3 Study Group was formed to discuss how best to approach running 10Gbps transmission over a copper infrastructure. This group is composed of representatives from chip manufacturers, switch manufacturers, and cabling and connectivity manufacturers. Discussions within the group include which protocol encoding to use and how it relates to the needed bandwidth or frequency range of the cabling infrastructure. As of this writing (May 2005), it appears as though the IEEE Study Group has recommended a frequency range out to 500 MHz.

A key measurement established by this IEEE study group is Shannon's Capacity. Shannon's Capacity is a measure of how efficiently a cable can transmit data at different rates, expressed in bits per second. The IEEE 802.3 Study Group concluded that achieving 10Gbps transmission, at 100 meters requires at least 18Gbps from the cabling solution. The additional capacity is required to compensate for active hardware noise parameters such as jitter and quantization.

Realizing that the cabling plant is designed to support the requirements of active electronics, a Shannon's Capacity of at least 18Gbps is a good measure to consider when evaluating 10Gbps UTP solutions.

ADC's CopperTen 10Gbps UTP solution demonstrated 21Gbps over 100 meters for the IEEE 802.3 Study Group in August 2003, easily exceeding the Shannon's Capacity minimum requirement of 18Gbps for all pair combinations. Today, CopperTen has achieved greater than 31 Gbps over 100 meters—offering more than enough additional throughput to handle noise induced by active electronics.

Have vendors had a tough time achieving 10Gbps over UTP at 100 meters?

Yes. By August 2003, the IEEE 802.3 Study Group had seen no vendor UTP solution that could deliver 18Gbps over UTP at 100 meters. In fact, the apparent lack of vendor solutions led the IEEE Study Group to three possible recommendations: lower the data rate to 2.5Gbps for Category 6 UTP; reduce the length of the supported channel to 55 meters from the industry standard 100 meters for Category 6 UTP; and use shielded solutions and abandon UTP as a transport medium for 10Gbps over copper.

KRONE, recently acquired by ADC, took on the challenge and returned to the IEEE 802.3 Study Group just weeks later to demonstrate CopperTen, the first augmented Category 6 cable capable of transmitting at least 18Gbps over 100 meters. After this demonstration, the IEEE 802.3 Study Group voted 64 to 0 to move forward with a 10Gbps solution over UTP at 100 meters.

What is the biggest challenge to achieving a minimum of 18Gbps over UTP?

For Category 5e and Category 6 solutions, the pair-to-pair relationship is paramount to making good cable. While these electrical characteristics remain important, taming alien crosstalk remains the toughest hurdle for any 10Gbps UTP solution at 100 meters.

Alien crosstalk is the noise heard on a pair within a cable that is generated by another cable directly adjacent to it. Manufacturers of active equipment do not like random events such as alien crosstalk. While noise between pairs within a cable can be predicted and eliminated within the active hardware, unpredictable alien crosstalk cannot.

Crosstalk between pairs in a single UTP cable is often cancelled out by varying the twist rate between different pairs and increasing the distance between pairs. The often-used star filler of Category 6 cable creates separation by pushing pairs within the cable as close to the jacket as possible. While this design reduces crosstalk between pairs within the same cable, it leaves some pair combinations between cables in the bundle susceptible to high levels of crosstalk. This problem is magnified at the higher frequencies of 500 MHz to 625 MHz of 10Gbps transmission.

Instead of using the typical star filler, ADC's CopperTen uses an elliptical offset star filler that achieves a high degree of separation between pairs in adjacent cables in a bundle. The shape of the elongated star filler results in an oblique shape for each cable. Bundled cables now have sufficient separation between same lay length pairs to prevent alien crosstalk. In a bundle, the random separation of cables keeps cable pairs of the same twist rate within different cables at a greater distance from one another—reducing alien crosstalk.

Because alien crosstalk presents the steepest challenge to 10Gbps over UTP, insist on seeing test results for the 6-around-1 cable configuration.

Is cable insulation important?

Choice of insulation materials is critical in producing 10Gbps UTP cable. One key measure of insulation quality is the Dielectric Constant—the lower the Dielectric Constant of the insulation material of a cable, the better the resistance to breakdown when an electrical field is applied.

As a reference, the Dielectric Constant of air—the best insulation available—is 1.0. Dielectric Constants for other cable insulation materials are as follows: FEP—2.1; FRPE—2.5; PVC—3.6; glass—4.3. The choice of insulation materials plays a large part in cable performance.

Insulation affects the speed at which a signal propagates through a cable. Speed is measured as the Nominal Velocity of Propagation (NVP), expressed as a percentage of the speed of light in a vacuum (300 million m/sec), with the speed of light in a vacuum given a value of 1.

The speed of the signal over a multi-pair data communications cable can be attributed to two main factors: the speed at which the signal is traveling (NVP) and the total length of the cable pair, which allows for twist rate. Both of these parameters combined are measured as Propagation Delay, the time it takes for a signal to propagate from one end of a circuit to the other.

Therefore, cable constructed with insulation with a lower Dielectric Constant—offering less resistance to an electrical field—offers a higher NVP.

Insulation for ADC's CopperTen cabling system uses the unique AirEs technology that combines FEP with integrated air pocket channels. Through the introduction of air pockets between the FEP and copper conductor, the total Dielectric Constant is reduced from 2.0 for FEP alone to about 1.8 for FEP with air—a 31%improvement over an FEP-only insulation system. The reduced dielectric loss translates into a direct improvement in signal loss—and improved NVP or, said differently, stronger signal strength.

Of course, other 10Gbps cables may use only FEP or FRPE insulation—both of which have a higher Dielectric Constant that weakens signal strength. Improving the Dielectric Constant of FEP by adding air—the AireES technology—offers higher performance cable for 10Gbps transmission.

Why is electrical cable pair length important?

The choice of cable insulation plays a role in electrical cable pair length. Besides NVP, the other factor that affects the speed of a signal over a multi-pair communications cable is the electrical length of the cable pair. Electrical length is always more than physical length of the sheath due to twisting of the conductors.

As described above, the effect of faster NVP is low Propagation Delay. However, Propagation Delay is also a function of the actual length of the pair, including the twist. The greater the twist rate, the longer the pair—and the larger the Propagation Delay. In fact, excessive propagation delay is often due to cable that is just too long.

By utilizing the higher quality AirES insulation with air channels between FEP and the copper conductor, CopperTen cable requires a reduced amount of twist on each pair. By reducing the electrical length of pairs, Propagation Delay is reduced, improving the speed of the signal between transmitter and receiver—especially important as cabling runs reach the 100 meter physical limit.

What is the impact of Delay Skew on 10Gbps cable performance?

Delay Skew is the difference in time each signal requires to arrive on all four pairs. Of course, optimal performance and error free transmission means that signals should arrive at the receiver as close to the same time as possible. Delay skew of 45nS to 50nS between the fastest and the slowest pairs is marginally acceptable for data communications. Lower skew is better. Delay skew below 25nS is desirable.

To achieve Near End Cross Talk (NEXT) performance, most cable solutions must vary the twist lays greatly. NEXT is, of course, more of a problem at higher frequencies, such as with the 500MHz or better for 10Gbps solutions. To solve NEXT, some solutions actually use different insulation for different pairs within the same sheath, which ends up as unique twist ratios (i.e, varying electrical length of cable pairs) per pair. Unfortunately, greater variation in twist lays means an increase in Delay Skew—a costly compromise when it comes to data communications. While receivers can handle slight variations is delay, a large skew will make it impossible to recombine the original signal.

With the AirES innovation of introducing air—the best insulator against noise—as an insulator, crosstalk is reduced without having to greatly increase twist lay variation. There is simply less crosstalk between pairs because of reduced noise due to superior insulation. Therefore, AirES technology and reduced need for twist lay variation results in fewer bit errors as the propagation delay between the fastest and slowest pairs is less than 20nS.

How should warranty promises be evaluated?

Until 568B.2 is ratified, it is impossible for any vendor to guarantee full compliance to a standard that does not yet exist. Until standards are established, it is more important for a 10Gbps UTP solution to meet the throughput and capacity requirements established by the electronics industry—Shannon's Capacity of 18Gbps. As the standards evolve, manufacturers will continually tweak individual parameters such as NEXT and return loss, as we saw with Category 5e and Category 6. Still, the only hard design number for 10Gbps over UTP today is 18Gbps throughput as defined by IEEE.

ADC offers a warranty that backs 18Gbps channel capacity and supports the current draft of 568B.2 Addendum 10.

Is cable diameter an issue with 10Gbps UTP solutions?

Larger cable diameters can affect not only density but also ease of installation and maintenance. To achieve the requirements of draft standards for 10Gbps transmission over UTP, some manufacturers today have 10Gbps UTP cable with outside diameters (OD) ranging from 0.310" to 0.330"—rather large in comparison to the nominal size for conduit fill of 0.290" for the plenum CopperTen, which has a varying OD from 0.275" to 0.310" due to its elliptical shape.

Outside diameter is also a consideration for patch cords. ADC's CopperTen patch cord cable has an OD of 0.270"—which is dramatically smaller when compared to the OD of the competitive cable which range from 0.310" to 0.330".

While these differences seem small, they become significant installation and maintenance issues, especially in dense applications.

Are patch cords changing for 10Gbps transmission?

There is one change to look for when evaluating patch cords for use in a 10Gbps channel—stranded vs. solid wire. Some products have moved to solid wire patch cords to achieve 10Gbps performance. Yet solid wire patch cords present concerns.

Patch cords that employ solid wire sacrifice flexibility and bend radii mechanics because solid wire is not as forgiving and easy to install or manage as stranded wire. Solid wire patch cord conductors are more prone to breakage when repeatedly flexed during normal lifetime usage. In addition, solid wire patch cords often have reliability issues due to the difficultly of crimping RJ45 plugs on solid wire. As compared to stranded wire patch cords, solid wire patch cords also place unnecessary stress upon the connectors in NICs, patch panels and switches, because of their uncompromising stature.

Conclusion

It is evident that 10Gbps transmission over a copper cabling plant will soon become the common design specification. While lack of standards today present some risk in the decision making process, other factors offer guidance when choosing cable, plugs and connectors to support future 10Gbps applications. Choosing a solution with the highest quality insulation—such as the AirEs technology used for CopperTen—offers immediate evidence of superior performance. Solutions that can guarantee Shannon's Capacity of 18Gbps at 100 meters offer the best assurance that the channel will support 10Gbps transmission when standards are ratified next year.

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