White Paper

Advanced Cabling Systems and Field Test Considerations

Structured cabling systems have evolved rapidly over the past 20 years and the driving factors for the growth in cabling technologies differ from those of just 10 years ago. Back then, providers rushed to adopt newer technologies and faster communications speeds and considerations for cost were secondary. Today, the evolution continues; however, as the industry emerges from recession, it is now driven by more pragmatic factors.

Bandwidth requirements continue to grow exponentially from 1 to 10 Gbps up to 40 to 100 Gbps. The landscape for preferred media has changed with office network connections becoming increasingly wireless for less-bandwidth-intensive applications. Until recently, 100Base-T over copper cabling was the dominant Ethernet technology for enterprise network users. Today, wireless technology is more prevalent for 100 Mbps communication links. For high-bandwidth links, particularly in data centers, fiber is increasingly justifiable; and technologies such as OM4 (multimode 50 µm laser-optimized fiber for high-speed applications defined in TIA 492AAAD) are making multimode fiber a viable option for 40 and 100 Gbps applications. Despite all these factors, the copper-structured cabling market is currently poised for double-digit growth and is forecasted to remain that way for the next several years. Applications such as voice over IP (VoIP), IP video, and power over Ethernet (PoE), and demand from growing economies such as China and India are driving this phenomenal growth. The question becomes: What happens after that? The fixed infrastructure and excessive cost and inconvenience associated with rewiring warrant that cabling last at least 10 to 15 years before rewiring again. Long-term planning requires consideration of the emerging possibility of 40-Gbps Ethernet even over copper-structured cabling. One report predicts that within 5 years at least 5 in 100 network links will be 40 Gbps.

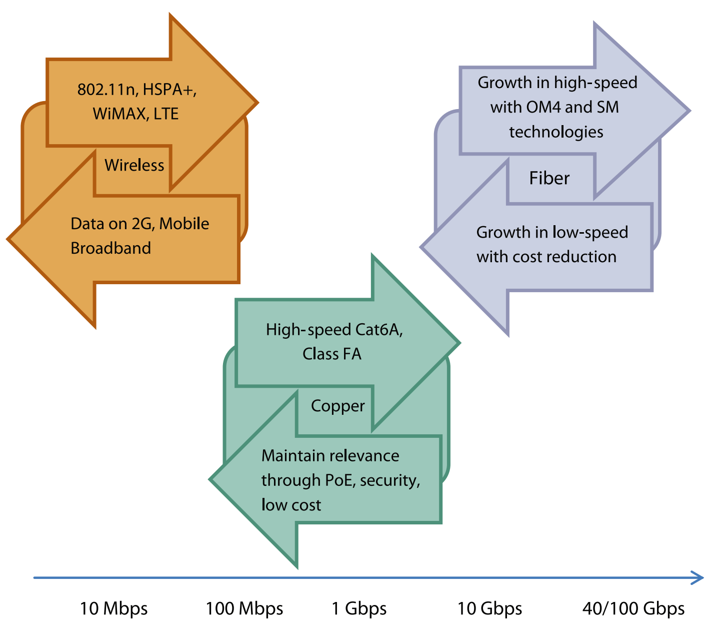

Figure 1 Communication media for enterprise networks

Copper-Structured Cabling and 40 Gbps

Industry research in 2005 and 2006 predicted a rapid adoption of 10GBase-T Ethernet over CAT6, CAT6A, and CAT7/Class F cables. In reality, its adoption has been significantly slower than predicted. The latest data suggests that the penetration of 10GBase-T as a percentage of total copper Ethernet remains a single-digit number, possibly because of the recent economic situation. Another more technical explanation relates to physical layer semiconductor devices that perform an enormous amount of signal processing. The power dissipation from these devices has been a major issue, because they necessitate sophisticated thermal management that is unnecessary in 1 Gbps Ethernet technologies or earlier generations.

Therefore, if 10 Gbps Ethernet is only now starting to see reasonable volumes, must we anticipate 40-Gbps Ethernet over structured cables? Also, on the other hand, as fiber becomes increasingly affordable, and the Institute of Electrical and Electronics Engineers (IEEE) has already defined a 40-Gbps Ethernet standard over fiber, will the evolution of copper cabling systems end at 10 Gbps?

Many experts in the industry and academy disagree with this view because copper cables provide such advantages as easy deployability, cost-effectiveness, and backwards compatibility. Copper cables also enable features such as PoE that further simplify installation. Besides, it makes great economic sense to be able to upgrade a large installed base of CAT6A and CAT7/7A cabling to carry 40 Gbps Ethernet. Note that besides the existing installed base, copper-structured cabling infrastructure is likely to grow rapidly over the next few years due to new applications, 10 Gbps adoption, and emerging markets. Considering these factors, a significant effort is now under way to devise methods for overcoming technical limitations that inhibit adoption of 40 Gbps Ethernet over copper cables.

Ethernet receivers resort to sophisticated signal processing techniques to predict and dynamically cancel out RF impairments. Effects of internal cable parameters such as near-end cross talk (NEXT), return loss, and attenuation can be dynamically canceled using Digital Signal Processing (DSP) techniques. Conversely, external interferences such as alien cross talk and noise from sources such as mobile devices or electrical switching transients are unpredictable. Several ideas have been presented about how to overcome the issues related to signal processing complexity in the physical layer devices. One possibility involves using superior RF performance of Class FA cables because they introduce less impairment; therefore, improving the signal quality arriving at the receiver which requires less effort (signal processing) to recover the signal. The second possibility involves using a wider frequency band, such as the 10GBase-T systems defined by IEEE802.3an, that use 400 MHz of bandwidth and employ 16-PAM encoding. At 40G, the encoding scheme might become far more dense if using a similar bandwidth. Dense encoding essentially means the receiver must distinguish between signals separated by smaller voltage and phase differences, which becomes increasingly difficult as RF impairments increase. Instead of defining a very high modulation density over a narrower frequency band, an alternative approach is to send signals over a very wide frequency band, which spreads the information over a much wider frequency spectrum thus containing the modulation density to a manageable level. One study recommended 1.6 GHz bandwidth utilization to enable transmission of a 40 Gbps data rate with standard CAT6A cables. An additional option, of course, is to define the operation for a shorter length of cable. Attenuation in twisted-pair cables rapidly increases with frequency and using shorter lengths enable transmission of much higher frequencies with detectable signal levels.

In addition to technical progress toward making higher than 10G communications feasible over copper-structured cabling, a new initiative proposes TIA incorporate the CAT7A standard, which is likely to open adoption of high-performance CAT7A/Class FA cabling systems in important markets in North America. It remains to be seen if and when the IEEE will consider standardizing 40GBase-T.

Field Testing for 40G Copper Cabling

While cabling and semiconductor technologies can ensure the feasibility of supporting 40 Gbps Ethernet (GbE) over twisted-pair copper cables, wide spread market adoption calls for additional considerations. One of the key elements is the availability of field test instruments to characterize and certify installed cabling for suitability to carry 40 GbE. Until now, field test instruments capable of characterizing RF parameters of the cable at frequencies as high as 1.6 GHz were unavailable. A combination of factors such as stringent performance requirements, maintaining low costs, providing a handheld form factor, and increased test speeds made it difficult for test equipment vendors to offer such a device. Unlike laboratory-grade vector network analyzers, field testers impose several constraints: they must be small, handheld, lightweight devices. They also must be battery operated with sufficient battery life to avoid recharging during a technician's workday. Therefore, it requires minimizing the power consumption of the measurement hardware. Additionally, these devices must be significantly low in cost compared to lab-grade network analyzers.

It is because of all of these factors that field testers on the market today can only support bandwidths of 1 GHz or lower. The advent of recent innovations in semiconductor devices driven by the proliferation of consumer-grade mobile RF gadgets, now enables commercially available testers to provide accurate measurements over a wide frequency range of 1 to 1600 MHz (1.6 GHz), which represents a significant increase in achievable test frequency range and also features better performance than test instruments currently available. IEC 61935-1 and TIA 1152 standards define characterization of parameters for field testers.

While discussing standards that determine field tester performance, note that the highest level of accuracy specification defined to date, known as the Level IV Spec, only covers a 600 MHz bandwidth. Therefore, standards committees must determine field tester accuracy specifications covering broader frequency ranges in the coming months and years.

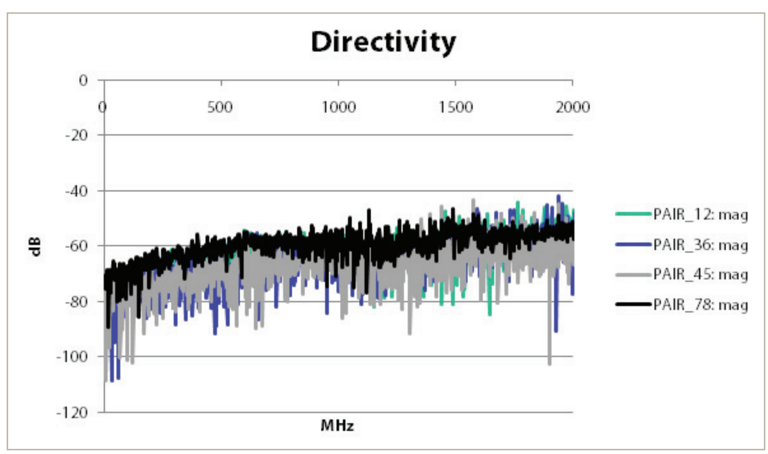

Figure 2. Directivity plot of new field tester suggests high accuracy RF measurements up to 2000 MHz

Conclusion

Despite recent growth in wireless and fiber infrastructure, copper cabling remains the predominant media for enterprise networks for the foreseeable future. Designing infrastructure for use over the next 15 to 20 years requires consideration of the high likelihood that 40GBase-T systems will be defined and become commonplace in 5 to 10 years. Of the technical challenges in supporting such high data rates, the main one is the complexity of physical layer devices. Studies and test data suggest that current cabling should work for 40GBase-T, made possible by extending the bandwidth usage over a cable link. In order to create a complete ecosystem for adoption of technologies such as 40GBase-T, the industry requires cabling systems, networking devices, standardization, and also field test instruments suitable for that technology. Several factors have constrained field testing over wider bandwidths in the past; and at least one commercially available field tester can certify cabling to bandwidths as high as 1600 MHz that also meets the field testing needs for future 40GBase-T systems.

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