Next Generation Communications Technologies and Implications for Copper Cabling

Our thanks to Psiber Data Systems for allowing us to reprint the following article.

During the past three decades communications technologies have seen dramatic evolution. One aspect of this evolution is bandwidth demand, which continues to grow exponentially from 1 Mbit/sec to 1 Gbit/sec to 10 Gbits/sec to 40 and 100 Gbits/sec. Second is the adoption of IP and internet, which led to convergence of media. Today most communications applications can use IP and Ethernet for exchanging information. Another phenomenon that has great impact is the huge growth in wireless communications systems; wireless has become the most common medium for personal communications.

Interestingly, the growth story of communications technologies is not limited to speed. It is about accessibility. Breaking technological limits of performance in terms of speed is one objective. But on the other hand, there are innovations on application space that utilize available technologies more effectively for the society. There are several examples to illustrate this:

- On one hand, technologies like HSPA+, WiMAX, and LTE push the data rates on mobile devices higher towards tens of megabits/second; and on the other hand there is a proliferation of applications that use low speed wireless technologies like SMS more effectively.
- Optical fiber communications links are enabling extremely high speed communication links over large distances. At the same time, there is huge growth in use of lower cost fiber for end-user access applications like FTTH.
- The story for copper cabling systems is a similar one. On one hand, the industry is heading towards 40 Gbps speeds on structured copper cabling systems. On the other hand, copper structured cables are proving to be low cost and unified medium for applications including security and power distribution to data equipment.

Copper Structured Cabling and 40Gbps

There are many skeptics who believe that structure cabling will lose its relevance after 10GBASE-T. They have reasons to believe so given that copper cabling systems are challenged from wireless and fiber. For applications that are not very bandwidth intensive, primary access mechanism is increasingly wireless. For high bandwidth links particularly in data centers, fiber is increasingly justifiable. Despite these factors, the fact remains that copper structured cabling market is poised for a double digit growth rate in 2011. This level of growth is forecasted to last at least next five years, driven by applications like VoIP, IP video, and PoE, and demand from growing economies like China and India. The question is what happens after five years.

Recent developments suggest that copper structured cabling systems are here to stay. In fact, copper is poised to be dominant connectivity method for data centers. Main reasons: copper is still lower in cost and requires less skilled work force to install compared to fiber. Data Center managers are looking to lower the cost of infrastructure and want the flexibility in moves, adds, changes that comes with copper structured cabling. Besides, large portion of data center links are short distance, well within the capability of twisted pair cabling for carrying 40Gbps bandwidth. Network equipment companies are considering 40G copper (which probably will be called 40GBASE-T) as a cost effective migration path to 40G while also providing backwards compatibility. Networking semiconductor companies are looking at 40GBASE-T as new growth opportunity. Copper cable vendors clearly have strong interest in ensuring relevance and growth of copper cabling systems. Building owners with huge installed base of copper cables also see great value in having relatively seamless transition to 40G on copper. Given all these market drivers, arrival of 40GBASE-T appears certain.

The skeptics have one more reason to be pessimistic. Industry research in years 2005/2006 predicted a rapid adoption of 10GBASE-T Ethernet over CAT6, CAT6A, and CAT7/Class F cables. The real adoption has been significantly slower than predicted. The latest data suggest that the penetration of 10GBASE-T as a percentage of total copper Ethernet is still a single digit number. One reason for that possibly is the economic situation over past few years. Another reason is more technical, and relates to physical layer (PHY) semiconductor devices. The power dissipation from PHY devices has been a major issue, because they necessitate sophisticated thermal management which was not needed in 1Gbps and earlier generations of Ethernet technologies.

Ethernet receivers dissipate considerable amount of heat; which is primarily due to sophisticated signal processing techniques to predict and dynamically cancel out RF impairments. Effects of internal cable parameters like NEXT, Return Loss, and attenuation can be dynamically cancelled using DSP techniques. On the other hand, external interferences like alien cross-talk and noise from sources like mobile devices or electrical switching transients are not predictable. There have been ideas on how to overcome the issues related to signal processing complexity in the Ethernet receiver.

One possibility is to utilize superior RF performance of Class FA cables. As these cables introduce less impairment, the signal quality arriving at the receiver is expected to be better and hence call for less effort (signal processing) to recover the signal. Second possibility is to use wider frequency band. 10GBASE-T systems defined by IEEE802.3an use 400MHz bandwidth and employ 16-PAM encoding. At 40G, encoding scheme might become far denser if a similar bandwidth is used. Dense encoding essentially means the receiver has to distinguish between signals separated by smaller voltage and phase. This task becomes increasingly difficult as RF impairments increase.

Instead of defining very high modulation density over a narrower frequency band, an alternative approach is to send signals over a very wide frequency band. As the information of the signal is now spread over a much wider frequency spectrum, modulation density can be contained to a manageable level. One study has recommended 1.6GHz bandwidth utilization to make standard CAT6A cables capable of transmitting 40 Gbps data rate. 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 by using shorter lengths, much higher frequencies can be transmitted with detectable signal levels.

Standardization activities

Standardization bodies are actively looking into various aspects of higher than 10G transmission on structured copper cables. TIA has started a new project to define next generation cabling systems. As part of the project, four task groups have been formed to study different aspects. First is *Capacity task group*. Its objective is to determine technical parameters like overall noise model (NEXT, FEXT, reflection, external noise), and capability of PHY devices to cancel noise, power consumption, bandwidth requirements. Second, *Application space task* group attempts to determine what applications will be served e.g. 40G Ethernet, what topology e.g. data center server links, what constraints e.g. limited length, limited number of connectors. The other two task groups, Cable task group and connector task group, will translate the capacity and application requirements into cable and connector requirements. Similar work has also begun in ISO. IEEE will have ultimate responsibility of defining 40GBASE-T specifications, and the progress there is driven by equipment manufacturers and cabling companies.

Field Testing for 40G Copper Cabling

While cabling and semiconductor technologies can ensure feasibility of supporting 40Gbps Ethernet over twisted pair copper cables, wide spread market adoption calls for additional considerations. One of the key elements is availability of field test instruments to characterize and certify installed cabling for suitability for 40GbE. Unlike laboratory grade vector network analyzers, field testers are constrained by several limitations. They need to be small, handheld, light weight, low cost devices. They also need to be battery operated with long battery life, so that the installation technicians can avoid the hassle of recharging the testers in the middle of their work day. This essentially means that the power consumption of the measurement hardware must be minimized. It is because of all these factors that field testers till recently could only support 1GHz or smaller bandwidth.

With the advent of recent innovations in semiconductor devices, driven by proliferation of consumer grade mobile RF gadgets, now a tester that provides accurate measurements over a wide frequency range from 1 MHz to 1600 MHz (1.6 GHz) is commercially available. It represents not only significant increase in achievable test frequency range, but also features better performance than currently available test instruments. Characterization of parameters for field testers is defined in IEC 61935-1 and TIA 1152 standards. Figure 2 shows the performance of this tester in relation to one such parameter, directivity, a parameter determining how accurately a tester can measure return loss.

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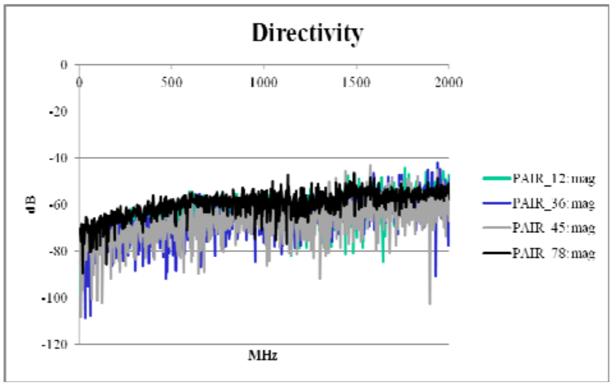

Figure 1: directivity plot of new field tester suggests high accuracy RF measurements up to 2000MHz

While discussing about standards that determine field tester performance, it should be noted that highest level of accuracy spec defined till date, so called level IV spec, only covers 600MHz bandwidth. It will become important for standards committees to come up with field tester accuracy specifications covering broader frequency range in coming months and years.

Conclusion

Despite the growth in wireless and fiber infrastructure, copper cabling will still be the dominant media for enterprise networks in a foreseeable future. When designing infrastructure for use over next 15 to 20 years, one must consider the fact that there is a high likelihood that 40GBASE-T systems will be defined, and become common-place in 5-10 years. There are technical challenges in supporting such high data rates, one of the main challenges being complexity of physical layer devices.

There are studies and test data that suggest that cabling available today should work for 40GBASE-T. This would be made possible by extending the bandwidth usage over a cable link. In order to create a complete eco system for adoption of technologies like 40GBASE-T, the industry will need cabling systems, networking devices, standardization, and also field test instruments suitable for that technology. Field testing over wider bandwidth has been constrained in the past due to several factors, but now at least one commercially available field tester features capability of certifying cabling to bandwidths as high as 1600 MHz, which is expected to meet field testing needs for future 40GBASE-T systems.

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