Hype-Performance Cabling

Buddy Shipley

As Gigabit Ethernet-over-copper rolls out, get ready for new cabling standards—and new problems as well.

Running Gigabit Ethernet over copper is a growing requirement as organizations begin to saturate some of their Fast Ethernet segments. Backbones and server connections are the first to fill these 100-Mbps pipes, creating network-wide bottlenecks.

One interim solution is port trunking, or bonding multiple 100Base-TX Fast Ethernet segments in parallel. This method allows two, three, four or more 100-Mbps, full-duplex, Fast Ethernet connections to be aggregated into one big "pipe."

But such solutions typically are proprietary. It's more appealing to migrate high-demand connections to IEEE 802.3ab 1000Base-T Gigabit Ethernet using a single, full-duplex connection, rather than multiple, smaller aggregated connections.

Price is always an issue with new technologies, and Gigabit Ethernet is no exception, especially when relying on fiber media. While the price of fiber cabling is not generally an obstacle, the opto-electrical interfaces can be expensive. 1000Base-T uses a less expensive copper interface to support the familiar TIA/EIA 568-A Category 5 or Category 5e unshielded twisted pair (UTP).

Why Cat 5 May Not Be Enough

1000Base-T Gigabit Ethernet transmits and receives in both directions simultaneously over all four copper pairs (bidirectional, dual-duplex transmission). By comparison, 100Base-TX Fast Ethernet can also support full-duplex operation, but it transmits on one pair and receives on a separate pair.

Category 5 cable was designed for applications using only one pair (out of four) at a time, and 100Base-TX Fast Ethernet uses only one pair to transmit at 100 Mbps. (100Base-T4 does not support full-duplex operation.) Although it seems to adequately support such connections, Cat5's specifications were not designed with concurrent transmissions over multiple pairs, let alone bi-directional dual-duplex, in mind.

As a result, as of 2Q00, the original Category 5 horizontal installation specifications will no longer be supported by the EIA/TIA; those specs are being replaced with the Category 5e certification. Cat5e tightens some Cat5 parameters (NEXT, FEXT, Return Loss), and adds several new requirements (e.g., Power Sum NEXT, Power Sum Equal Level FEXT). The installation requirements for Cat5e (and for Category 6) are the same as for Cat5—minimal jacket removal (~1″) and pairs may be untwisted no more than half an inch (see Table 1 for a summary of characteristics for Categories 3–7).

In order to support full-duplex operation at 1,000 Mbps, 1000Base-T Gigabit Ethernet requires all four pairs to concurrently pump 250 Mbps; all four pairs must support full-duplex, bidirectional communications. In other words, rather than using different pairs of conductors to transmit than those used to receive (as in full-duplex 100Base-TX), 1000Base-T uses one

TABLE 1 Cabling Standards—Existing and Under Development

Cable Category	Media Type	Channel Length	Spectral B/W	Pair Untwist	Applications Supported
Cat3	UTP	100m	16 MHz	N/A	4Mb TR, 10Base-T
Cat4	UTP	100m	20 MHz	1″	4 & 16Mb TR, 10Base-T
Cat5	UTP	100m	100 MHz	.5″	100Base-TX, 1000Base-T
Cat5e	UTP	100m	100 MHz	.5″	100Base-TX, 1000Base-T
Cat6	UTP	100m	250 MHz	.5″	1000Base-T
Cat7	STP	N/A	600 MHz	N/A	N/A

100VG AnyLAN, 100Base-T4 and 100Base-T2 are also supported by Cat3.
CDDI and ATM are also supported by Cat5, as are all lesser applications.

Source: Author, who recommends also visiting www.anixter.com/privnet/tsol/d0804p33.htm for additional details.

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conductor of each pair to transmit 250 Mbps and the other conductor to receive 250 Mbps. And it does this on all four pairs simultaneously.

Rocky Road to Category 6

Because 1000Base-T transmits over all four pairs, most of the signal received over UTP is reflected noise. To overcome the inherent limitations of Cat5 cabling and to discern the data from the noise, 1000Base-T relies on extensive and expensive digital signal processing (DSP) electronics. The DSP must cancel the noise and be able to read the attenuated transmitted signal.

Initially it was thought that the DSP circuitry would require about 1 million transistors (approximately the horsepower of an 80486 CPU), but it is apparently requiring more than three times that much—about 3.5 million transistors (approximately the horsepower of an early Pentium CPU). The DSP electronics are required on each adapter and switch interface, which drives up the price of 1000Base-T hardware.

Given its more stringent performance requirements, even Cat5e cabling has limitations that potentially prevent Gigabit Ethernet from performing reliably. There is no patch cord specification yet, which is scary because 65 percent of *all* Cat5 patch cords still fail the latest NEXT requirements (defined in the new Addendum 4). Moreover, Cat5e does not provide an excess of "headroom" over the performance requirements of 1000Base-T; there is little margin for error.

Work is now progressing on Cat6, and at least four groups are developing specifications:

- ANSI, which competes with IEC and ISO as the overall "oversight" group. Once completed, TIA/EIA 568-XXX will eventually become an ANSI standard. TIA/EIA are responsible for the current TIA/EIA568-A cabling standards, including definitions for Cat3, Cat4, Cat5 and Cat5e cabling specifications. The TIA/EIA specs for Cat6 will not be completed until later this year.
- The National Electrical Manufacturers Association's (NEMA) WC66 Category 6 standard was published about a year ago, and it has been submitted to the TIA/EIA for consideration.
- The ICEA (Insulated Conductors Engineer Association) is writing a Category 6 specification.
- The ISO/IEC 11801 WG3 is defining yet another Category 6 specification, however they are reportedly bogged down in connector "intermateability" issues (i.e., making a full range of plugs—poor to high-quality—work with any jack). In a rather Orwellian move, rather than amending its documents with the new term—Category 5e (Cat5e)—ISO will keep the original Category 5 (Cat5) nomenclature and simply change the performance specifications.

So, remember, Category 6 is not yet finalized, and make sure you know which—if any—standard your vendor claims to be adhering to. While some vendors are already touting—and selling—"Cat6" cabling products, interoperability problems are inevitable and certification methodologies have yet to be worked out.

Pete Lockhart, Anixter's vice president of technology and product design, confirms three key difficulties: Connector "intermateability," the lack of a patch-cord specification and lack of vendor interoperability. To help address these problems, Anixter (www.anixter.com) created the Anixter Levels Channel (ALC) program, which, according to Lockhart, "is a proprietary purchasing spec that our partners sign to be able to sell through Anixter....We want the cables and connectivity to work as components just the way the suppliers say they will, and to work well in matched systems.

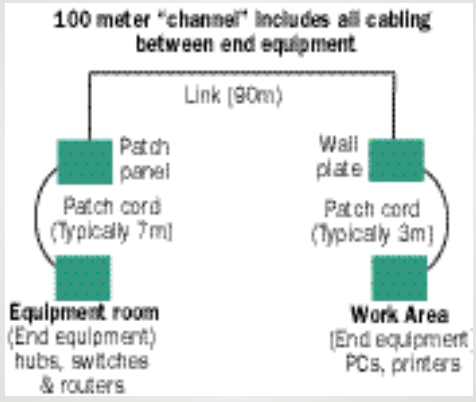
"We are trying to cut through the marketing hype that goes with these products," he continued. "If a supplier claims 'better-than-standards' performance, our specs spell out at least 20 ways his stuff must be 'better-than'."

James Hayes, president of Fotec, Inc. (www.fotec.com), explained that several media test methods are supported by the standards, and each generates very different results. Stranded media patch leads used with test instruments are problematic, because manipulating the cables alters the strand geometry, which in turn affects the cable's impedance. (This stuff is sensitive!) Furthermore, if the patch cords used with a test instrument to determine Cat6 channel certification are ultimately exchanged for other patch cords to connect the network hardware, the channel certification will be rendered invalid.

Despite these problems, however, Dave Sorensen at Broadcom (www.broadcom.com), a chip and hardware manufacturer, maintains enough work has been done to get products out into the market: "The actual standard is the result of more than five years of work involving nearly 1,000 of the networking industry's most experienced engineers, including many from the cable manufacturers and the EIA/TIA. Broadcom spent more than 18 months testing and modeling cable plants, and dozens of other companies also went through this analysis to develop a very precise understanding of what goes on in thousands of

While some vendors are already selling "Cat6" products, interoperability problems are inevitable

FIGURE 1 Cable Plant Terms



Backward-compatibility with Cat5 is also proving to be a problem for Cat6

New Media For The New Millennium

Prepare for the arrival of the new millennium by installing a new medium! Fiber has been getting cheaper and easier to terminate and install every year. Maybe it's finally time to consider an all-fiber network.

Fiber to the desktop has been discussed for many years, but always dismissed due to the significantly higher costs. Certainly, if you simply plan to replace UTP horizontal cable runs on each floor with fiber, the cost would be dramatically higher. But fiber segments can support distances much greater than the 100-meter limitation of UTP. This means fewer wiring closets are required along with the associated equipment (hubs, switches, routers, patch panels, rack systems, UPSs, et al).

Rather than terminating all horizontal cable runs in one or more wiring closets on each floor, consider extending the cable runs from the desktops to a single, central wiring facility. Of course, it would require larger space than the typical wiring closet, but the expensive closet space formerly required on each floor could be reduced or eliminated.

Telephony closets may still be required—unless traditional telephony migrates to IP packet technology so that it can use the same cable plant (hmmm?). Common perceptions of fiber installation costs frequently fail to include such radically different cable plant designs.

Unfortunately, perceptions define reality, which means that most people are operating under the misconception that fiber is too expensive to consider. But with the third millennium about to begin, fiber alternatives deserve closer examination□

different real-world channels and how to best deal with them.

"The result of all this work," he continued, "has been a standard that the IEEE believes will allow 1000Base-T to run successfully on more than 90 percent of the cable plants that can presently support Fast Ethernet. Our experience shows that 1000Base-T does indeed work on the existing cable plant."

While TIA/EIA standards require that Cat6 cabling components be backward compatible with those of Cat5, this also is proving to be a significant obstacle. According to Pete Lockhart of Anixter, "This is in part due to the fact that the TIA/EIA writes performance specifications, not design specifications. The standards define the electrical characteristics of a given media, but not how to achieve those characteristics. The engineering teams of the cabling manufacturers then design their media to comply with the performance specifications."

For example, the engineers of Company A make certain decisions and compromises to meet or exceed a given set of performance specifications. The engineers of Company B make different decisions and compromises to achieve the same goals, which may create conflicts with cabling from Company A. The result is an imbalanced cable plant, or more accurately, an imbalanced channel, wherever products from the two companies are mixed (Figure 1, p. 31).

Almost everyone interviewed seemed to agree that any customers who buy from multiple vendors are asking for problems. The consensus is that to achieve a reliable Cat6 cable plant, you must use cable and cabling components that are designed to work together—in short, buy from a single vendor. And forget about making your own patch cords in-house—buy them from the same vendor who provides your cabling.

Is Cat6 viable? "It's not that the technology isn't viable, it's the implementation," Lockhart said. "The implementer must have total control over the entire cable plant, including all parts (premises cabling, patch cords, patch panels, station cords, and wall plates). This has not been the case in most cable plant implementations."

Departments with their own budgets have often obtained patch cords and even augmented their cable plants on their own, by buying cabling and components from a plethora of providers. Lockhart said, "If you expect a reliable Cat6 cable plant that can support Gigabit Ethernet, that [practice] can no longer be permitted."

Tradeoffs Vary by Standard and Products

While everyone agrees that Gigabit Ethernet will run over unshielded twisted pair, there are significant differences in how the standards bodies are approaching the problem. For example, the IEEE 1000Base-T (802.3ab) spec relies on more expensive electronics to support cheaper Cat5 cable, while TIA's 1000Base-TX (PN-4657) relies on more expensive Cat6 cabling to support cheaper electronics. In essence, the IEEE places the burden on the digital and electronic side (relying on DSP hardware), while the TIA places the burden on the analog and cabling side.

In other words, the electronics vendors want to solve the problems with electronics-based technology, and the cabling vendors want to solve them with cabling-based technology. Cat6 cable costs about 30 percent more than a good quality Cat5. The price differential between 1000Base-T copper interfaces and 1000Base-SX fiber interface ranges from $200–$560.

According to Luc Adriaenssens, director, Lucent Systimax R&D, "The complexity of 1000Base-TX is about one-tenth that of 1000Base-T. This translates into chip size and

Hardware vendors say Cat6 is unnecessary and uncertain; cabling vendors say Cat6 can overcome hardware shortcomings

power reduction savings, facilitating lower-cost packaging, quad packaging, simple power management, etc. How this translates into price will depend on market dynamics, profit models, etc.

"For instance, 1000Base-TX could be priced at only a modest 25 percent premium over 100Base-TX to quickly drive desktop volume and migration to the faster speed, but this simply isn't possible with 1000Base-T due to the underlying complexity," he continued. "A reasonable assumption is that 1000Base-TX cards will initially be priced at half that of 1000Base-T cards. This will cover the cabling premium many times over. What happens after that will depend on market dynamics. It will be fun to watch it all play out!"

However, according to David Sorensen of Broadcom, "The 1000Base-TX proposal was rejected several times by the IEEE 802.3, and is not being supported by any of the networking equipment manufacturers. The essential difference is in the requirement for echo cancellation in the four-pair, bidirectional IEEE approach and dealing with the faster frequencies and EMI issues on the 2×2-pair unidirectional approach."

Sorensen claimed, "As process technology progresses, the DSP-heavy approach scales, while the analog approach does not. The difference in die size between the two approaches will become insignificant over time."

He continued, "[The unsuccessful] 100Base-T4 and 100VG-AnyLAN had support of the IEEE, but not the network equipment manufacturers. TIA 1000Base-TX has neither." Sorensen believes that availability will be the biggest issue between IEEE 802.3ab 1000Base-T and the proposal from the TIA. 1000Base-T adapters will certainly be available first, but the future of 1000Base-TX appears dubious. When Intel announces its new GigE-over-copper products later this month, the market will get a good indication of which way this issue will turn out.

Although most of the expense of the Gigabit Ethernet physical layer (PHY) chips is due to the complexity of the DSPs required to overcome Cat5 deficiencies, John Siemon, president of The Siemon Company (www.siemon.com), said, "Economies of scale should drive costs down. [The DSP approach] should be cheaper than recabling, and is cost-competitive with fiber."

Beware of the Hype

With all the different standards bodies working on specs, and with the various vendors supporting one spec over the others, rumors, claims and counter-claims about high-performance cabling are flying in all directions. For example, hardware vendors insist that Category 6 cabling is unnecessary and uncertain, while cabling vendors insist that superior Cat6 cabling would eliminate the need for expensive and over-engineered hardware.

However, many of those cabling vendors neglect to mention the issues and obstacles

Are You Ready for Cat 7?

While the ink isn't dry on the Category 6 standards—indeed the spec isn't even complete—some folks are already starting to tout Category 7. Well, contrary to what you might have heard, Category 7 is nowhere near completion.

When it is finished, however, get ready for a major change: Cat7 will not be unshielded twisted pair; instead, it will be shielded. It also will be significantly more complex and costly to install than any UTP installation, because each pair will be individually shielded and another overall shield will wrap all four shielded pairs. Rather than using the familiar and inexpensive eight-position modular connectors (RJ-45s), Cat7 will require an entirely new interface design.

While Cat7 promises much greater bandwidth—600 MHz— than its predecessors, the cabling market in the U.S. has collectively cast its vote against shielded twisted pair (STP). We've learned that UTP, if properly engineered and installed, can overcome most of the problems STP is supposed to correct. Moreover, an improperly installed or damaged shielded system can be worse than having no shield at all. For example, STP shielding must be maintained 360° around the cable end-to-end without interruption. Lucent's Luc Adriaenssens notes that for STP to gain the benefit of the shield it must be grounded at both ends, but this can cause ground loops. Grounding the shield only at one end can make the cable susceptible to AM radio interference.

Those with valid concerns about electromagnetic or radio interference (EMI/RFI)—e.g., those in heavy manufacturing or who are in locations where there's arc welding—should consider using fiber rather than STP. Since optical fiber uses photons instead of electrons, it is not susceptible to EMI/RFI; an arc welder cannot affect fiber transmissions unless it is dropped on the fiber.

In support of Cat7, John Siemon argues, "As transmission frequencies go higher, FCC restrictions will create obstacles." He maintains that while Cat7 has problems, opportunities for the technology exist as we move to higher and higher speeds.

"Cat7 will be glass" according to Fotec's James Hayes, and Anixter's Pete Lockhart tends to agree. However, it should be noted that fiber solutions are not without their own upgrade issues—there are several incompatible connectors currently in use and no clear direction for future products. So much for a "future-proof" cable plant□

surrounding Cat5, Cat5e and Cat6. As noted above, some already are hawking pre-standard products as being "Category 6-compliant" (or even going beyond the capabilities of the spec), even though the standards are incomplete. Moreover, rarely is any mention made of backward compatibility or of likely interoperability problems.

The most annoying hype is the myriad vendor claims of "future-proof" solutions. If there's one lesson the history of this industry teaches, it's that there is no such thing as "future-proof."

According to Lucent's Adriaenssens, "Some vendors are promoting products that are not backward-compatible nor interoperable, and these products will not be compliant once the standards are complete. Category 6 cabling must meet all specifications of the lesser categories." Adriaenssens also pointed out that while Cat6 channel specifications have been stable since the end of 1997, there still are some differences between the ISO and TIAspecifications.

This is not to say that the performance claims made by some cabling vendors have no validity. For example, Belden's DataTwist 350+ UTP product is certified to 350 MHz, while the specs only require certification out to 100 MHz. This translates to greater margin for error and greater "headroom"—i.e., greater bandwidth leeway, which makes it easier to install a cable plant that's within spec and, perhaps, extend the life expectancy of the cable plant. Note, however, there are no standard certification parameters defined for frequencies above 100 MHz.

In an effort to stay ahead of the wave, certification instrument vendors (e.g., Agilent, Fluke, Microtest, WaveTek) are selling tools that, reportedly, are capable of certifying Cat5, Cat5e, Cat6 and higher cables. These vendors acknowledge that the current standards are incomplete, and most will provide upgrades once the certification standards become finalized.

In an effort to help you navigate through the minefield, here's a summary of the relevant facts, as best as I can assemble them to date:

- Cat5 UTP is quickly being replaced by Cat5e.
- Existing Cat5 installations *may* support GigE.
- New Cat5e installations *should* support Gigabit Ethernet, but there is little tolerance for error—i.e., lack of headroom (as with Cat5).
- Problems with some cable runs might be corrected by retrofitting Cat5 cable ends with Cat5e components.
- Cat5e UTP will likely be quickly eclipsed by Cat6 UTP.
- Cat6 UTP may be the last major advancement in UTP technology.
- All future Cat6 installations *will* support Gigabit Ethernet.

If history teaches us anything, it's that no solution is "future-proof"

Implementation Recommendations

What wiring approach will work best for you? That depends both on your requirements and your point of view. Here are some ways of looking at your options.

- **For the Frugal:** A good quality Cat5 cable plant will easily support 100Base-TX Fast Ethernet, although there are no guarantees that Cat5 or Cat5e will reliably support 1000Base-T Gigabit Ethernet. Therefore, if you're going to install a new cable plant to support 100Base-T Fast Ethernet, buy the best Cat5 cable and components you can afford. Do not cut corners and do not skimp on components.

  Installation must comply with EIA/TIA 568-A, plus 569 pathways and spaces, and 607 grounding. Have every cable run certified. Since Gigabit Ethernet to the desktop is unlikely to be a requirement in the near future, server and switch interconnections can be provided using Cat6 or fiber in select locations. Fiber is strongly recommended for all backbone and server connections.
- **Focus on the Future:** So you want the option of supporting 1000Base-T Gigabit Ethernet to the desktop and want to run Gigabit Ethernet on UTP? If you're going to install a new UTP cable plant now, buy the best Cat5e or Cat6 UTP cabling and components you can find (preferably from a single vendor or, at least, components that are designed and guaranteed to work together) and have it installed as professionally as possible.

  Installation must be *fully* EIA/TIA568-B compliant (once the standard is ratified). If you skimp on anything now, you are an idiot. Since channel certification is dubious, buy all cabling and components from a single vendor and get he best you can. Fiber is strongly recommended for all backbone and server connections.
- **Focus on Fiber:** If you want to support 1000Base-T Gigabit Ethernet to the desktop now, but aren't confident that it will run reliably on UTP, go with fiber. Fiber will easily support Gigabit Ethernet and eliminate the problems that have plagued UTP cable plants. Of course, fiber requires different installation tools and training, and many of the components (switches, router interfaces, network interface cards, etc.) are more expensive.

  However, cost savings may be realized by the elimination of equipment in every wiring closet on every floor in every building, and by the elimination of the closets themselves. And don't forget to run UTP for the telephony gear! The opto-electronics cost a bit more and port density is still an issue□

Are Gigabit Ethernet and Cat6 the end of the line for UTP?

- Cat6 provides ample headroom or margin for 1000Base-T Gigabit Ethernet.
- Cat6 would be a requirement for the future TIA 1000Base-TX Gigabit Ethernet.
- TIA 1000Base-TX leaves less headroom or margin over Cat6 than IEEE 1000Base-T.
- Cat7 STP will likely be prohibitively expensive and have few applications (see "Are You Ready for Cat7?").
- On the topic of margin, almost everyone agrees that wider is better.

Conclusion

Gigabit Ethernet to the desktop is currently unrealistic, because very few desktop computers can take advantage of that much bandwidth. The bottlenecks include not only the CPU, system board architecture and backplane, but the network interface cards, operating systems and applications. Although most PCs cannot even saturate a 100-Mbps connection, Gigabit Ethernet is definitely useful for high-end server connections and switch-to-switch interconnections.

"We saw dramatic changes in the marketplace after 1997 when hardware vendors began including DSP circuitry onboard to overcome cabling deficiencies." Pete Lockhart explained. "10Base-T, 100Base-TX and 1000Base-T may work over a shoddy cable plant, but you will not realize the full benefit of the technology."

Engineers can design and manufacture UTP cabling capable of supporting gigabit-per-second transmissions, but the likelihood that a high percentage of such installations can be properly installed and pass certification remains dubious. As noted above, a substantial percentage of Category 5 cable runs are improperly installed and can't pass certification.

So, do Gigabit Ethernet and Cat6 finally exhaust the realistic bandwidth that UTP can offer? I hesitate to draw such a conclusion, because similar questions were asked when 10Base-T and 100Base-T came on the scene, and clearly they have little to no problems running over UTP. Lucent's Adriaenssens says "1000Base-T-over-Cat6 is bulletproof because 1000Base-T was designed for Cat5/5e just as 10Base-T-over-Cat5 is bulletproof because 10Base-T was designed for less than Cat3."

While GigE is a huge leap forward in bandwidth accompanied by another leap in engineering and certification requirements, technological advancements appear to be up to the challenge. And if we have reached the upper limits of the medium with the new hyper-performing copper, there's always fiber□

The BCR Business Review

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