Category 6 Cabling - The Simple Solution for Gigabit Applications

L. A. Baxter,P.E. & M.A. Shariff
Bell Laboratories of Lucent Technologies
200 Laurel Avenue, Middletown, New Jersey 07748, U.S.A

ABSTRACT

Category 6 cabling has been talked about ever since category 5 cabling was introduced more than 6 years ago. In September 1997, the ISO/IEC/JTC1/SC25/WG3 committee responsible for the IS 11801 Generic Cabling for Customer Premises, decided to pursue the development of Category 6 cabling. This paper outlines the context in which this decision was made, tracing the evolution of category 3, category 5, and now category 6. The channel requirements of the ISO/IEC draft category 6 specification are explained and compared to category 5 channel requirements. Using the models and equations to represent transmission performance of a 100 meter channel, mechanisms for deriving component requirements from the channel requirements are discussed. The paper also relates category 6 cabling to the Gigabit applications currently under development by describing various simplifications in the electronics that are possible with a higher performance cabling system. The paper concludes with the long term benefits to application developers and end users of a category 6 cabling system.

I. BACKGROUND

Category 5 cable was first specified by the Telecommunications Industry Association (TIA) in TSB-36 in November, 1991 and Category 5 connecting hardware was specified in TSB-40 in August, 1992. Category 5 link and channel performance was initially specified in TSB-67, which was issued in October, 1995. Almost since the inception of Category 5, there has been speculation about Category 6. In February, 1997 TIA established a work project (PN 3727) to investigate specifications for a next-generation Unshielded Twisted Pair (UTP) cabling system. TIA has established objectives for the Category 6 cabling and is developing complete system specifications.

To understand the need for better cabling, we need to look at the rapid increase in LAN speeds over the past few years that has resulted in unprecedented demands on the supporting cabling infrastructure. Driven by the worldwide dominance of Ethernet networks, LAN speeds have risen from 10 Mb/s to 100 Mb/s and soon will reach 1 Gb/s, as shown in Figure 1.

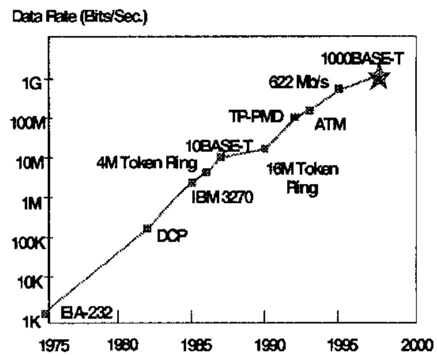

Figure 1 – LAN Data Rates

II. UNDERSTANDING CABLING SPECIFICATIONS

Figure 2 shows the pin-outs of a modular jack. To meet the standards, the Near-End Crosstalk (NEXT) values for all 6 combinations of pairs must be within the specifications. Occasionally, a vendor will advertise outstanding cross-talk performance for a particular pair combination (normally pairs 2 and 4, which are the easiest pairs to optimize). Since one cannot control which pairs applications will use, and Gigabit Ethernet will use all 4, NEXT specifications must be given for the worst of all the pair combinations.

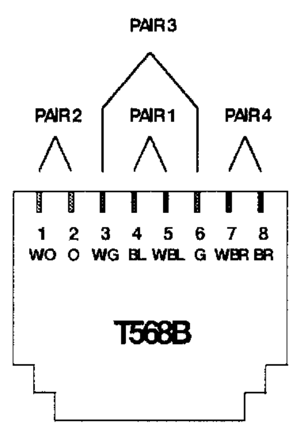

Figure 2 – Modular Jack Pinouts

Figure 3 illustrates a typical channel. Looking into the channel from the closet end (the left side of the figure), there are 2 connectors in close proximity. Looking from the work area end, there is only one connector nearby. Since NEXT is a near-end phenomenon, the performance from the work area end of the channel will be superior to the performance measured from the closet end. The true system performance is represented by the worst-performing end of the channel. If results are reported from the work-area end, or if an average of work-area and closet measurements are given, then the values will be a few dB better than the true performance of the system.

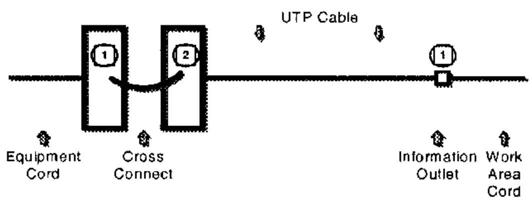

Figure 3 -- Typical Channel

III. CATEGORY 6 CHANNEL REQUIREMENTS

Category 6 channel requirements were derived based on a specific set of objectives that were established in TIA and ISO. These objectives are listed below:

- The system must represent a significant improvement over Category 5. The current proposal is a delta of at least 2 times the Category 5 frequency spectrum (i.e., 200 MHz) with maximum attenuation and minimum multi-disturber NEXT similar to Category 5 at 100 MHz. In other words, the system must perform as well at 200 MHz as Category 5 performs at 100 MHz.

- The next generation cabling shall be backward compatible with existing Category 5 cabling. It will be a "strict super-set of Category 5" as requested by the IEEE. This implies:
  A) The modular jack interface shall be maintained for all user interfaces at the work area.
  B) Next generation components will be electrically compatible with those of the other categories. In other words, if you mix Category 5 and Category 6 components in a link or channel, you should get at least Category 5 performance.

- Next generation cabling shall be a system specification including procedures for laboratory and field testing, installation practices, and other practical considerations (e.g., reliability, durability, etc.) This is a direct result of the experience with Category 5, where the channel testing specifications lagged the component specifications by more than 3 years.

- The EIA/TIA TR 41.8.1 committee will actively solicit input from application committees such as the IEEE and ATM Forum to incorporate the needs of future applications, including new parameters.

- Next generation cabling shall meet the horizontal cabling topology (100m) as specified in TIA-568A and TIA-569A.

International cabling standards are developed by a joint committee of the International Organization for Standardization (ISO) and the International Electrotechnical Committee (IEC), which is conveniently known as ISO/IEC SC35/WG3 (hereafter referred to as 'WG3'). At their September 1997 meeting in Munich, Germany, WG3 reached the historic decision to develop Cat 6/Class E specifications. The WG3 Category 6 specification will be based on expected world-class UTP cabling performance by the year 2000. It must be a superset of Category 5 (including the modular jack interface) and must have useable bandwidth up to 200 MHz.

At the same meeting, WG3 issued a draft of proposed Category-6/Class E channel specifications (Figure 4). Note that these specifications meet all the objectives set by the TIA committee. It is likely that this specification, or something very close to it, will be adopted by both the US and international standards bodies.

Notice that both TIA and ISO/IEC specified that backwards compatibility with existing cabling systems is required. This is a very important point. There is no installed base of Category 6 LAN equipment -- existing LAN equipment (hubs, NICs, etc.) expects to work with Category 5 cabling,. Until true Category 6 LAN equipment appears on the market, all connections to equipment will be a mixture of Category 5 and Category 6 because of the Category 5 jacks installed in the LAN equipment. High performance cabling that is not backwards compatible with Category 5 will likely cause performance problems with current LAN equipment.

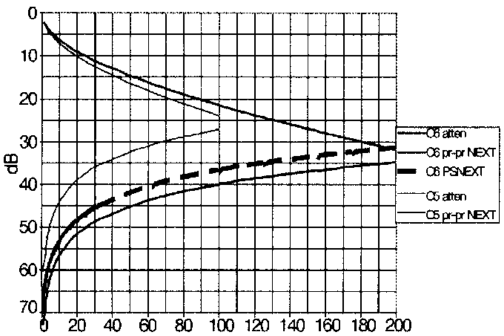

Figure 4 -- Draft Category 6 Specifications

IV. CATEGORY 6 COMPONENT REQUIREMENTS

ISO WG3 uses a "top down" design approach to specify the cabling system as one alternative. Initially, this approach helps to arrive at design targets more easily. The challenge then is to derive matching component parameters that will result in the channel requirements when combined using an appropriate model. TIA and ISO both use a worst case voltage or vector sum model to add component parameters to derive channel parameters.

The general approach used to specify category 6 parameters is for a category 6 channel to have the same performance at 200 MHz that a category 5 channel has at 100 MHz. For example, if the Equal-Level Far-End Crosstalk (ELFEXT) requirement for a category 5 channel is 18 dB at 100 MHz, the target for a category 6 channel is to achieve an ELFEXT of 18 dB at 200 MHz. Knowing the target values and the equations that characterize different parameters, the following channel and component specifications have been proposed in the ISO WG3 committee and will become the basis for discussions in TIA.

A. Attenuation

Attenuation of cabling and connectors is a function of the frequency *f* and can be expressed as a simple sum of the individual cable and connector component attenuation.

$$\text{Attenuation}_{link} = \sum \text{attenuation}_{connectors} + \sum \text{attenuation}_{cable}$$

The attenuation of 100 meters of category 6 cable is specified by:

$$Attenuation_{cable} = 1.02\left(1.82\sqrt{f} + 0.023f + \frac{0.050}{\sqrt{f}}\right)$$

The factor 1.02 assumes that the total 10 meters of patch cords allowed in a channel have an attenuation 20 % greater than the horizontal cable.

The attenuation of each category 6 mated connection is specified from frequency f 1 to 200 MHz by:

$$Attenuation_{connectors} = 0.02\sqrt{f}$$

A maximum of 4 mated connections are allowed in a 100 meter channel.

B. NEXT

Assuming worst case voltage sum addition and two connections at the near end, the NEXT of a category 6 channel at frequency f from 1 to 200 MHz is specified by:

$$NEXT_{channel} = -20\log\left(10^{-\frac{NEXT_{cable}}{20}} + 2 * 10^{-\frac{NEXT_{conn}}{20}}\right)$$

The NEXT of category 6 cable is specified by :

$$NEXT_{cable} = 74.3 - 15\log(f)$$

The NEXT of connecting hardware is specified by:

$$NEXT_{connecting\_hardware} = 94 - 20\log(f)$$

C. ELFEXT

Assuming worst case voltage sum addition and a total of 4 connections in a 100 meter channel, the ELFEXT of a category 6 channel at frequency f from 1 to 200 MHz is specified by:

$$ELFEXT_{channel} = -20\log\left(10^{-\frac{ELFEXT_{cable}}{20}} + 4 * 10^{-\frac{FEXT_{connectorr}}{20}}\right)$$

The pair-to-pair ELFEXT of category 6 cable is specified by :

$$ELFEXT_{cable} = 70 - 20\log\left(\frac{f}{0.772}\right)$$

The pair-to-pair ELFEXT of connecting hardware is specified by:

$$FEXT_{connecting\_hardware} = 59 - 20\log(\frac{f}{16})$$

Note that for connecting hardware, FEXT is used as a reasonable approximation for ELFEXT.

V. GIGABIT ETHERNET OVER CATEGORY 5 CABLING

The IEEE 802.3ab committee is close to completing the 1000-BaseTX Gigabit Ethernet Specification. This specification is targeted to work over a "reasonable" portion of the installed base of category 5 cabling. Since the application uses simultaneous bi-directional transmission on all 4 pairs, additional cabling parameters are needed to support this application. These parameters are multi-disturber NEXT, multi-disturber FEXT , and return loss. Installed category 5 cabling will need to be tested for these parameters to ensure the cabling is suitable for the 1000-BaseTX application.

It must be pointed out that elaborate Digital Signal Processing (DSP) techniques are being used to implement 1000-BaseTX over category 5 cabling. These include NEXT cancelers, echo cancelers, adaptive equalizers, and decision feedback noise cancelers. This will add cost and complexity to equipment vendors. The expectation is that the large volume of the category 5 installed base will bring down the costs and justify the approach of designing complex electronics to overcome the limitations of a cabling system.

VI. SIMPLIFICATION OF GIGABIT ETHERNET OVER CATEGORY 6 CABLING

As data rates increase, applications are forced to complex technology to utilize existing cabling. If better cabling is available and has the potential to capture a significant portion of the market, application developers have historically moved to the better cabling since this will allow them to bring cheaper solutions to the market. This happened in the early 1990's as the market shifted from category 3 to category 5 cabling and most applications moved to category 5, making it the predominant cabling system worldwide. It is expected that this cycle of events will repeat as category 6 gets established in the standards and the market. Gigabit applications will move to the new cabling system and not require most of the DSP that had to be implemented to work over category 5 cabling. For example, the need for NEXT cancelers at both ends will not be necessary since category 6 cabling will have significantly higher NEXT isolation than category 5 cabling.

VII. CATEGORY 6 BENEFITS TO APPLICATION DEVELOPERS AND END USERS

Moore's law predicts that computing power will double every 18 months. More than 50% of workstations in the commercial environment are networked, and this figure continues to increase. These two statistics indicate that network speeds must keep pace with computing speeds to be able to support increasing information processing rates. For the end user, investing in a better cabling system is insurance to protect against the risk of the cabling system becoming obsolete. At present, category 6 is the best cabling available and provides backward compatibility, while providing twice the bandwidth to support emerging future applications. Category 6 will become the next most popular cabling system, so innovators who invest in category 6 cabling at a small premium will benefit because of the additional high speed applications that their cabling will support in the future. Standardization of Category 6 in TIA and ISO will ensure that the market remains open to products and systems from multiple sources.

VIII.SUMMARY

Category 6 is a high performance cabling system that is being standardized in both ISO and TIA. As they have done in the past, application committees will move to the better cabling to save equipment cost and complexity, while improving robustness and reliability. End user acceptance of category 6 cabling has been very positive and indications are that category 6 cabling will capture a significant portion of the cabling market worldwide. This should make category 6 the ubiquitous generic cabling system that supports voice to gigabit data applications using relatively simple electronics. The recommendation to end users is to select the best cabling available that supports both legacy and future LAN applications. Category 6 meets this criteria and will prove to be a wise investment.