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Category 6 Cabling
Questions and Answers

by

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Introduction

On June 20th, 2002, TIA finally published the Category 6 cabling standard. Now that this standard is a reality, many people are exhibiting renewed interest and are asking themselves - So what is Category 6 cabling? Does it look and behave differently than Category 5 / 5e? Will it supercede Category 5 / 5e? Does it work? Have all the issues been resolved? What does it mean for network performance? What are the applications that will work on Category 6 that don't work, or don't work as well, on Category 5e cabling? These are very good questions, and this paper will provide simple and impartial answers to these questions. For more information, a list of references is provided that explains bandwidth, cabling parameters and cabling performance in more detail.

What is Cat 6?

"If it looks like Category 6, and it feels like Category 6, and it sounds like Category 6, then it must be Category 6! To feel comfortable with this argument, you need to know "What is Cat 6?" It is a cabling system comprised of components (cables, cords and connecting hardware) that have many features in common with Category 5 and 5e but also some significant differences. Let's look at some of these similarities and differences:

First of all, Category 6 components are specified to be interoperable between different vendor's products and are fully backward compatible with all lower categories. Interoperability means that Category 6 components from different vendors can be mixed and matched to form a minimally compliant Category 6 Channel. Backward compatibility means that a Category 6 component can be substituted in any existing Category 5 or 5e channel to give Category 5 or 5e performance respectively. Although being 'backward compatible' seems like an obvious feature, it is not quite as easy as it sounds from the manufacturers' point-of-view. Similarly, 'interoperability' seems obvious in today's world of 'open architectures', but this concept presented significant challenges for both TIA and the manufacturers alike. Like most good things, these features were not easy to create, but worth the benefits that they bring to the end-user community.

Second, all Category 6 components have the same nominal Impedance of 100 Ohms as Category 5 and 5e components, but have a tighter tolerance on Impedance variations. Impedance variations are specified in terms of a parameter called Return Loss. A higher value of Return Loss (in dB) means better Impedance matching between components and lower signal reflections and re-reflections. As a result, Category 6 provides better Bit Error Rate (BER) performance for Fast Ethernet (100BASE-TX) and Gigabit Ethernet (1000BASE-T) networks. More frequently occurring bit errors means that your expensive networking devices are caught in unproductive cycles of error detection and re-transmission. Fewer bit errors means that your network is accurately and rapidly transferring the information that drives your business and improves productivity.

Third, all the transmission parameters for Category 6 channels, permanent links and components are specified up to 250 MHz compared to 100 MHz for Category 5 and 5e. Annex A provides a detailed comparison of the transmission performance of Category 6 and Category 5e channels as specified in the published TIA standards.

There is a difference between the specified frequency range and the usable Bandwidth. Bandwidth is defined as the frequency range where the PSACR (Power Sum Attenuation-to-Crosstalk Ratio) is positive. Category 6 yields a Bandwidth* of 200 MHz at 20 °C for the most demanding 100 meter channel configurations compared to a bandwidth of 100 MHz for Category 5 / 5e. So if you consider Bandwidth to be the 'speedometer' for cabling systems, you will see that Category 6 effectively doubles the 'top speed' of earlier standards.

* Note: For more information see **Category 6 Requirements at 200 Mhz and 250 MHz**

Do Category 6 components behave differently than Category 5 / 5e?

One of the biggest observable differences is in the cable construction. From the outside, Category 6 cables have a larger overall diameter, to a greater or lesser extent depending on the design. The diameter of Category 6 cables are in the range of 0.21 to 0.25 inch (5.3 - 5.8 mm) compared to Category 5/ 5e, which is in the range of 0.19 to 0.22 inch (4.8 – 5.5 mm). This is because Category 6 cables are manufactured with larger copper conductors and may include an internal divider called a cross-web that serves to separate the pairs within the cable and reduce cross-talk noise. The cross-web divider to separate the pairs is not a specified requirement of the Cat 6 standard, and some manufacturers have developed designs and processes that deliver full Cat 6 compliance without the use of any physical dividers between pairs.

The reason for the larger conductor size (approx. 23 AWG) is to provide a lower Insertion Loss (also called Attenuation) over the specified frequency range. A lower Insertion Loss means a stronger signal at the Receiver compared with Category 5 / 5e. This improves the noise immunity to external and internal noise sources. Additionally, cables with a lower Insertion Loss can support longer distances or a higher temperature range for certain applications while continuing to deliver full Cat 6 performance. Even if you're not a cabling expert, most of us will recognize that lower Insertion Loss is the functional equivalent of a strong signal, and we all know that signal strength is the critical factor in overall network performance.

Another feature of Category 6 cables is a very tight twist length of 0.5 inches or less to reduce crosstalk interference between pairs. Altogether, these differences are analogous to buying a car. There are many different models to choose from that come in different sizes and shapes and with different features and performance. Category 6 cabling, with its larger conductors, internal dividers, and tighter twist lengths would be analogous to a high-end model delivering better performance and more capacity.

What about installation?

Category 6 cables and components are installed very much the same way as their Category 5 / 5e counterparts. However there are some design and installation issues that the contractor and the installer must pay greater attention to, including 1) the cable terminations and 2) the cable pathway fill. The larger physical cable diameter needs to be taken into account when routing cables at cross-connects and in provisioning cable pathways. When terminating Category 6 cables it is very important to ensure that the pair twists are maintained right up to the point of termination. It is particularly important to follow manufacturer's instructions for terminating connectors. A poor termination can significantly reduce performance margins (**Article: "Category 6 Testing in the Field"**) or cause test failures in the field.

Will Category 6 supercede Category 5 / 5e?

The answer is yes; the only question is "When"? Today, the choice for Category 6 tends to be an economic one. Like most newly introduced technologies, Category 6 systems currently command a price premium and the installed cost for Category 6 cabling can be about 20 % higher than Category 5e, depending on market conditions. Experience tells us that prices will decrease over time as acceptance and volume increases. Regardless of traditional technology life-cycle pricing, the benefits of Category 6 in terms of bandwidth, performance headroom, reliability and application support, need to be weighed against end user needs, planning horizon and budgetary constraints. From a cost/benefit perspective the doubling effect of Category 6 performance versus Category 5/5e performance for as little as a 20% pricing premium deserves careful consideration. And the equation improves if you factor in the reality that the 'technology window' and operational life span of Category 6 systems will far out reach Category5/5e systems.

So, even with a new technology, an old adage rings true; it may be 'penny wise, but pound foolish' to implement new Category 5/5e systems today only to be forced to replace them in the near future because continually evolving IT systems need Category 6 performance. To paraphrase from a famous film that suggested "If you build it, they will come", The Cat5/5e to Cat 6 migration would be better described as "If you don't build it, they are coming anyway!" As we see with all technologies, the needs for 'more' and 'faster' are inevitable and irresistible forces that must be considered in your cabling infrastructure decisions.

Have all the bugs been ironed out, and does Category 6 deliver what is promised?

The answer is 'yes'. There are no technical obstacles in the way. What took so long in completing the standard was the development of the test parameters and the test procedures that are used to qualify Category 6 components to ensure interoperability between different vendor's products. These specifications are in place and very much detailed. Category 6 connecting hardware needs to be qualified with a range of "high" and "low" test plugs that simulate worst case variations in the field. This means that a specific connector design may work optimally with certain plugs while only achieving minimum Cat 6 performance with other plugs. So while the important concept of interoperability is delivered in the Cat 6 standard, it is most likely that optimum performance would be achieved using connectors and cords from the same vendor.

A simple way to describe Category 6 connector performance is to think of a parameter called sensitivity and selectivity on radio or TV receivers. Let's take the example a Satellite Dish Receiver. When the technician comes to install the satellite dish he points it in the general direction of the satellite. While watching the signal level on the TV set or listening to an audible beeper, the technician adjusts the dish up and down, left and right to get the strongest signal. It is the same way with a plug / jack connection. There is a minimally acceptable signal level depending on the orientation of the dish and an optimum signal when it is in the best alignment. The Category 6 connector specification defines the deviation allowed and the minimum signal level to achieve interoperability.

So, as you can see, Cat 6 does deliver on its promise. As a member of the TIA subcommittee that developed Cat 6, NORDX/CDT had proposed that the 'next generation' cabling standard should specify additional performance margins to account for 'Alien Cross-talk' and the effects of temperature on cabling performance. Although consensus support for the NORDX/CDT proposal was only partly accommodated, the work done by the Engineering Committee is a significant accomplishment in the industry considering the level of detail, completeness and the quality of the Category 6 standard as delivered. In retrospect, a curious fact comes to mind that is true for all technology standards and perhaps especially true for cabling standards. New standards represent significant new performance targets that we must stretch while under development. On publication of the standard, these distant targets instantly transform from projected upper thresholds to the absolute minimum acceptable performance values allowed under that standard. While the Cat 6 might have gone further, the published standard provides a solid step forward and our vision of higher performance systems will be achieved through a natural evolution in the marketplace.

What about the performance of your network when Category 6 is installed compared with Category 5 /5e?

Whether Cat 6 or Cat5/5e, network performance effectively boils down to Signal-to-Noise Ratio at the Receiver. All the different noise sources need to be taken into account, including NEXT, FEXT, ILD Noise, Alien Crosstalk and Impulse noise. The biggest benefit of Category 6 cabling is the much-improved Signal-to-Noise Ratio (SNR) using the Bandwidth employed by today's applications and also for future applications. The main result is that Category 6 provides about 12 dB (or 16 times) better Signal-to-Noise Ratio compared to Category 5 / 5e over a wide frequency range. For a more detailed technical explanation of this phenomenon, please refer to a white paper on the subject entitled "Cat 6 vs. Cat 5 / 5e – How cabling parameters affect network performance" **Article: Cat 6 versus Cat5/5e**

Why do we need Cat 6?

A frequently asked question is why do we need Category 6? Isn't Category 5e good enough for what is needed today and in the foreseeable future? The answer is "probably Yes". Does that mean we are avoiding the question. No, it simply means that we can only answer with certainty for today, and can only postulate about the future. For today's applications, there has been some work done by others that indicates Category 6 provides higher Data Throughput (fewer bit errors) than Category 5e for 100BASE-TX and 1000BASE-T applications. This work shows that some network switch ports are at the limits of the IEEE 802.3ab standard (i.e. marginally compliant) and are more susceptible to cabling and temperature variations. NORDX are presently in the process of generating some information on the Data Throughput of Category 6 and Category 5e in the presence of outside noise.

What about future applications?

A TIA Standard is already in place for Gigabit over Category 6 (1000BASE-TX) that provides for a more cost-effective solution in the future. Another application that is quite demanding is broadband video that today runs over coaxial cable. Broadband video can be supported over Category 6 cabling at distances up to 100 meters and frequencies up to 550 MHz. Category 6 is particularly suited for this application because of the lower signal losses and better transmission performance at higher frequencies compared with Category 5 / 5e. Another application that is on the horizon is digital video. The direct digital signals from HD-SDI sources are at 1.5 Gb/s, which goes significantly beyond the capability of today's twisted pair Cat 5 / 5e copper networks. An analysis of the information capacity of Category 6 cabling with 200 MHz Bandwidth indicates that it could support data rates of 2 Gb/s using the same encoding scheme of 1000BASE-T at twice the clock rate.

Accepting that new installations should be better than Cat5e. Why not skip Cat 6 and go all the way to optical fiber?

Without even considering the issue of relative performance, the copper/fiber decision has been driven historically by the significant differences between the initial costs of copper versus fiber cabling plants, combined with the even greater differences between the costs of electrical versus optical networking devices. Overall, the comparatively high total cost of ownership for optical networking made it very difficult to justify for use in horizontal distribution except where environmental noise, or security, or ultra high performance requirements made copper solutions impractical or inoperable. Today, the cost differential between copper and fiber cabling is decreasing, however even as the cost of optical fiber becomes more comparable to copper, the

largest deterrent to the use of fiber continues to be the cost of the active optical networking equipment.

To research information for this article, we 'shopped' equipment prices and availability on the Internet. There are a plethora of choices that provide 100 Mb/s Fast Ethernet ports over copper to the desktop and fewer choices over fiber. Looking at relative prices from a leading manufacturer of networking equipment, a 48 port 100BASE-TX switch with two 1000BASE-X uplinks is $4500US (approx. $80US / port for 100 Mb/s) compared with $4900 US for a 12-port 100BASE-FX switch (approx. $400US / port). In this particular example, the cost per user port for the optical switch was more than 400% higher than its copper-based counterpart. Generally the cost of optical networking equipment is from 2 to 4 times higher than copper. As an alternative option, an end user can purchase a media converter with copper equipment. The added cost of media converters for multimode fiber is about $112.00 US / port for Fast Ethernet and $385US / port for Gigabit Ethernet (see reference: Frost & Sullivan), and some may be concerned over the reliability/manageability issues that may arise from introducing additional points-of-failure in the network. All this means that running fiber to the desk is not economically attractive for today's applications compared to copper, and the continually increasing performance envelop of copper cabling systems would seem to be more than adequate for horizontal distribution now and in the foreseeable future.

Another reason that supports high performance copper cabling to the desk is the need for remote powering for VoIP telephones and other devices. This is an important new development. IEEE is in the process of developing a DTE Powering standard that would enable end users to plug in a variety of devices into the data outlet connector in the wall. The networking equipment or the mid-span power source would detect and recognize the type of device, e.g. an IP phone, sensor, camera, etc. and deliver the appropriate power as required by the device. This is an important step towards a ubiquitous network that is designed for device independence. When powering remote devices, Category 6 cabling has advantages over Category 5e because of the lower DC resistance (23 AWG) and 'Pair Balance' recommendations, which is a new parameter for Category 6 components.

Conclusions

This paper has explained the major differences and similarities between Category 6 and Category 5e cabling, and provides the reasons why an end user should consider Category 6 cabling for new installations.

The new CAT 6 standard includes specific requirements for Interoperability between different vendors' products as well as full Backward Compatibility with all existing Category 5 / 5e cabling, as this was a major objective in the development of the standard.

From a performance perspective, if we use Bandwidth and Signal-to-Noise Ratio (SNR) as the key indicators of performance, Category 6 cabling provides twice the Bandwidth (200 MHz) and 16 times (12 dB) better than Signal-to-Noise margins compared with Category 5e cabling. These additional performance margins compensate for deficiencies in the equipment and external noise and temperature variations in the environment. Category 6 is well positioned to support demanding applications such as multi-channel broadband video with an extended frequency range up to 550 MHz and digital video signals as high as 2 Gb/s for HD-SDI and future multi-Gigabit applications. Category 6 cabling is also a better alternative to fiber-to-the-desk because the cost of electronics is significantly lower for copper compared to fiber. Lastly, the new IEEE standards for remote powering of DTE equipment would be better served with Category 6 cabling because of the lower power dissipation for Category 6 cables and the improved balance recommendations for Category 6 components.

All together, these performance improvements offered by Cat 6 systems means higher capacity, throughput and productivity for your networks and your users. The forward-looking Cat 6 specifications should produce an extended operational life span and protection of your Cat 6 infrastructure investment. This combination of performance, longevity, and investment protection, along with the new attributes of interoperability and backward compatibility, makes Category 6 the smart choice for all new cabling system implementations.

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References:

- **Category 6 Requirements at 200 Mhz and 250 MHz**
- **Article: "Category 6 Testing in the Field"**
- **Article: Cat 6 versus Cat5/5e**
- Frost & Sullivan, North American Premises Wiring Market, A040-62 **www.frost.com**

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Annex A

Category 6 Channel Transmission Performance

Frequency MHz	Ins. Loss Max (dB)	NEXT Min (dB)	ACR Min (dB)	PSNEXT Min (dB)	PSACR Min (dB)	ELFEXT Min (dB)	PSELFEXT Min (dB)	Return Loss Min (dB)	Prop. Delay Max (ns/100m)	Delay Skew Max (ns/100m)
1	2.1	>65	>62.9	>62	>59.9	63.3	60.3	19	580	50
4	4	63	59	60.5	56.5	51.2	48.2	19	562	50
8	5.7	58.2	52.5	55.6	49.9	45.2	42.2	19	557	50
10	6.3	56.6	50.3	54	47.7	43.3	40.3	19	555	50
16	8	53.2	45.2	50.6	42.6	39.2	36.2	18	553	50
20	9	51.6	42.6	49	40	37.2	34.2	17.5	552	50
25	10.1	50	39.9	47.3	37.2	35.3	32.3	17	551	50
31.25	11.4	48.4	37	45.7	34.3	33.4	30.4	16.5	550	50
62.5	16.5	43.4	26.9	40.6	24.1	27.3	24.3	14	549	50
100	21.3	39.9	18.6	37.1	15.8	23.3	20.3	12	548	50
200	31.5	34.8	3.3	31.9	0.4	17.2	14.2	9	547	50
250	35.9	33.1	-2.8	30.2	-5.7	15.3	12.3	8	546	50

Category 5e Channel Transmission Performance

Frequency MHz	Ins. Loss Max (dB)	NEXT Min (dB)	ACR Min (dB)	PSNEXT Min (dB)	PSACR Min (dB)	ELFEXT Min (dB)	PSELFEXT Min (dB)	Return Loss Min (dB)	Prop. Delay Max (ns/100m)	Delay Skew Max (ns/100m)
1	2.2	>60	>57.8	>57	>54.8	57.4	54.4	17	580	50
4	4.5	53.5	49	50.5	46	45.4	42.4	17	562	50
8	6.3	48.6	42.3	45.6	39.3	39.3	36.3	17	557	50
10	7.1	47	39.9	44	36.9	37.4	34.4	17	555	50
16	9.1	43.6	34.5	40.6	31.5	33.3	30.3	17	553	50
20	10.2	42	31.8	39	28.8	31.4	28.4	17	552	50
25	11.4	40.3	28.9	37.3	25.9	29.4	26.4	16	551	50
31.25	12.9	38.7	25.8	35.7	22.8	27.5	24.5	15.1	550	50
62.5	18.6	33.6	15	30.6	12	21.5	18.5	12.1	549	50
100	24	30.1	6.1	27.1	3.1	17.4	14.4	10	548	50

Difference in Channel Transmission Performance (Cat 6 vs. Cat 5e)

Frequency MHz	Ins. Loss Max (dB)	NEXT Min (dB)	ACR Min (dB)	PSNEXT Min (dB)	PSACR Min (dB)	ELFEXT Min (dB)	PSELFEXT Min (dB)	Return Loss Min (dB)	Prop. Delay Max (ns/100m)	Delay Skew Max (ns/100m)
1	-0.1	>5	>5	>5	>5	5.9	5.9	2	0	0
4	-0.5	9.5	10	10	10.5	5.8	5.8	2	0	0
8	-0.6	9.6	10.2	10	10.6	5.9	5.9	2	0	0
10	-0.8	9.6	10.4	10	10.8	5.9	5.9	2	0	0
16	-1.1	9.6	10.7	10	11.1	5.9	5.9	1	0	0
20	-1.2	9.6	10.8	10	11.2	5.8	5.8	0.5	0	0
25	-1.3	9.7	11	10	11.3	5.9	5.9	1	0	0
31.25	-1.5	9.7	11.2	10	11.5	5.9	5.9	1.4	0	0
62.5	-2.1	9.8	11.9	10	12.1	5.8	5.8	1.9	0	0
100	-2.7	9.8	12.5	10	12.7	5.9	5.9	2	0	0

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