Cabling Lifecycles and Total Cost of Ownership

There are several factors that must be taken into consideration when determining the category or class of cabling that will be used in a network infrastructure. This is true for both copper and fiber. Factors that must be taken into consideration are:

- Expected installed lifetime of the cabling plant
- Applications that will run on the cabling plant over its useful life
- Timeframe during which standards, applications and electronics manufacturers will support the cabling plant
- Cost of active electronics
- Warranty length and covered components
- Price as it relates to performance
- Time the end-user will occupy a facility

What the standards mean to your network

With the IEEE 802.3an 10GBASE-T standard complete, performance demands on cabling infrastructures are expected to increase over the next few years. Cabling typically represents 5-7% of an overall network budget. Some specialty materials such as industrial rated products, conduit and limited combustible products may increase costs slightly higher. However, relying on price as the sole deciding factor is rarely a wise decision. Cabling systems, both copper and fiber, are designed to perform for 10 years, supporting 2-3 generations of active electronics. Overall lifecycle costs should be closely considered.

Cabling standards are regularly written and reviewed. For instance, ANSI/TIA/EIA (Now TIA) standards are reviewed every 5 years. At the end of the 5-year period they may be reaffirmed, rescinded or revised. ISO/IEC standards are written with a target lifespan of 10 years. IEEE application performance standards are written, revised or amended based on current manufacturing and product capabilities, application needs and contributions from companies, including cabling manufacturers, that participate in the standards process.

In some instances, overall network capabilities change at a greater pace than originally expected. This can shorten the lifecycle of a cabling system. Category 4 is a good example. This cable had a very short lifecycle due to expanding network performance requirements and the capabilities of higher performing category 5 and, eventually, category 5e. With the advent of 10GBASE-T, a higher performing category 6 cable known as Augmented Category 6 (6A) has been introduced. So the question is posed: how do I maximize my cabling investment, and what category of cabling should I install in my facility?

Active electronic manufacturers design equipment based on three factors: capabilities of the underlying infrastructure, industry standards and market share of the installed base of infrastructure. The technology must be technically feasible, have broad market appeal, and provide a unique feature set while coexisting with other technology. It would be virtually impossible to sell any active equipment that automatically requires replacement of a cabling plant.

Based on estimates from the major chip manufacturers, each iteration of a chip costs a developer approximately $1,000,000.00 and requires roughly 18 months from conception to market. Facing costs like these, most equipment producers are hesitant to venture too far from the standards. As standards eliminate or rescind support for cabling systems, the active equipment manufacturers will, as history shows, follow suit. There is an intricate balance between forward movement in technology and addressing the needs of legacy systems. In discussions within the 10GBASE-T study group, all categories, including 5e, category 6 and category 7/Class F, were examined to determine what the cabling would support and market share percentage held by each category. While category 5e has a greater market share, the cabling was not capable of supporting 10G b/s over distances more than 15 or 20 meters. Understanding that networks people have installed cabling lengths in excess of this limited distance, category 5e was written out of the standard and is not being considered. The final cabling choices for the pending 10GBASE-T standard is installed legacy category 6 with a supported distance up to 55 meters, augmented category 6 and category 7/class F, with the latter two supporting a distance of up to 100 meters.

It is important to note that the TIA 942 Data Center standard states that all horizontal cables shall be run to accommodate growth so that the horizontal does not need to be revisited. This is due to the significant cost and risk of downtime to adjacent systems. It is estimated that a data center will be in service for a period of 20 years and 10GBASE-T electronics will be added within 2-5 years.

Part of the cabling system selection process should include the cost of the cabling itself as well as other factors that contribute to the overall cost over its lifetime. As mentioned previously, a cabling infrastructure should last a customer 10 years and support 2 - 3 iterations of active equipment and applications. A costly factor in these calculations is labor, which may vary depending on geographic location; therefore national averages will be used.

The following analysis compares the total cost of ownership for a 24 channel cabling system ranging from category 5e through category 7/class F. Plenum-rated cable is used in all instances. Initial installation cost include the cost of components, installation and testing.

	Installed Cost	Lifecycle of System	Per Channel Average	Annualized Cost of Ownership
Cat 5e/Class D UTP	$4,103.66	5	$170.99	$820.73
Cat 6/Class E UTP	$5,560.74	7	$231.70	$794.39
10G 6A UTP	$8,129.86	10	$338.74	$812.99
10G 6A F/UTP	$9,026.24	10	$376.09	$902.62
TERA-Class F/Cat 7	$13,482.56	15	$561.77	$898.84

System life cycles are based on current standards developments, pending revisions, and the category's ability to support upcoming applications. For example, non-augmented category 6 systems will have a lesser lifecycle than augmented category 6 (6A) systems capable of supporting 10GBASE-T up to 100 meters. Category 7/Class F systems enjoy the longest lifecycle and are expected to support future applications beyond 10GBASE-T such as 40 Gb/s. The lifecycle costs for category 7/class F systems do not include the TERA®'s ability to run multiple 1 or 2-pair applications over one 4-pair cable and outlet which would make the TERA figures more attractive.

The previous table demonstrates that due to the shortened lifecycle of category 5e, the annualized cost of cat 5e (total installed cost divided by number of useful years) is near 10G 6A UTP. It is expected that during the next 2 -5 years, new 10GBASE-T copper electronics will be available and a cabling upgrade from 5e to at least augmented cat 6 (6A) will be necessary to support 10GBASE-T. It is fully expected that in the next 5-7 years, category 5e systems will move to an archive annex in their respective standards documents and will no longer be supported in the active equipment standards. Such was the case with category 3, 4 and 5 systems.

If a category 5e cabling plant was installed prior to adoption of additional performance parameters specified to support Gigabit Ethernet, the cabling plant should be retested for these parameters according to the latest standards. If we factor in the added labor to retest a legacy category 5e cabling plant, the total annualized cost increases. The following table shows additional lifetime costs of a 5e system compared to higher performing systems.

24 Channels	Installed Cost	Lifecycle of System	Annualized Cost	Incremental Testing for Gig	5 year Cost	New Annualized Cost of Ownership
Cat 5e/Class D UTP	$4,103.66	5	$820.73	$1,560.00	$5,663.66	$1,132.73
Cat 6/Class E UTP	$5,560.74	7	$794.39		$5,560.74	$794.39
10 G 6A™ UTP	$8,129.86	10	$812.99		$8,129.86	$812.99
10G 6A F/UTP	$9,026.24	10	$902.62		$9,026.24	$902.62
TERA®- Class F/Cat 7	$13,482.56	15	$898.84		$13,482.56	$898.84

In the above table, it becomes clear that over time, installation of a 5e system would cost significantly more. The figures above assume normal hours of operation and do not take into account overtime or other premiums that may be charged if the work is performed after hours to minimize disruption of the workforce.

It is important to note that category 5e is not being considered in the development of the pending IEEE 802.3an 10GBASE-T standard, In order to upgrade to support future 10GBASE-T applications (which is likely to occur over the next 10 years) additional labor will be required for both installation of the higher performing augmented category 6 cabling as well as removal of abandoned category 5e cable as now required by fire codes and legislation in many countries. In the category 6 UTP model, incremental labor is also added to test and verify 10GBASE-T support for channel lengths up to 55m as outlined in IEEE 802.3an as well as the corresponding TIA and ISO/IEC standards. According to recent work in the standards, 55m will only be viable with some type of mitigation to reduce the Alien Crosstalk. Again, we are not accounting for after-hours installation or tracing cables if the labeling and documentation on the system was not maintained. The cost to replace or run new conduit or drill new cores as needed to accommodate the new circuits due to increased cable diameters are not included. (See "New 10G Installation Practices" below).

24 Channels	Cost at 1Gig	Testing for 10GBASE-T	Removal of Abandoned Cables	Installation of 10G Capable Channels*	TCO to support 10GBASE-T	New Annualized Cost of Ownership
Cat 5e/Class D UTP	$5,663.66	Not-Supported	$1,560.00	New system required	New TCO applies	$1,444.73
Cat 6/Class E UTP	$5,560.74	$1,560.00	$390.00	$2,032.47	$9,543.21	$1,363.32
10G 6A UTP	$8,129.86	N/A	–	–	$8,129.86	$812.99
10G 6A F/UTP	$9,026.24	N/A	–	–	$9,026.24	$902.62
TERA - Class F/Cat 7	$13,482.56	N/A	–	–	$13,482.56	$898.84

*NOTE: The annualized cost of ownership stops after the removal of the abandoned cable and does not factor in the installation of the replacement 10G capable system. This is because the ROI/TCO calculation for the new 10G system starts with its installation. Cat 6/Class E UTP costs are based on replacement of 1 in 4 channels due to distances exceeding 55m as outlined in the standard. Costs for mitigation to support 55m are not included.

Factoring in Downtime Costs

If we consider downtime costs while testing and replacing the non-compliant 10G systems, the cat 5e and 6 total cost of ownership figures continue to increase. As cable testing is intrusive (the device at the other end must be disconnected in order to test), some downtime will occur with each iteration of testing and remediation.

Hourly employee costs will be estimated at the national hourly average wage as reported by the US Bureau of Labor Statistics weighted to account for overhead. For instance, the national average annual wage is $33,252.09. Adding overhead (taxes, office space, etc. using a 40% estimate) the figure is $46,562.66. On an hourly basis, the figure is $22.39 per employee per hour. This cost covers the expense of an employee being paid and unable to work. For each 24 employees that are down for one hour (time to shutdown, have their cable traced, tested, reinitialize their systems, and log on to applications, etc), the additional downtime costs for each 24-port system is calculated as follows:

24 employees * $22.39 per hour = $537.3

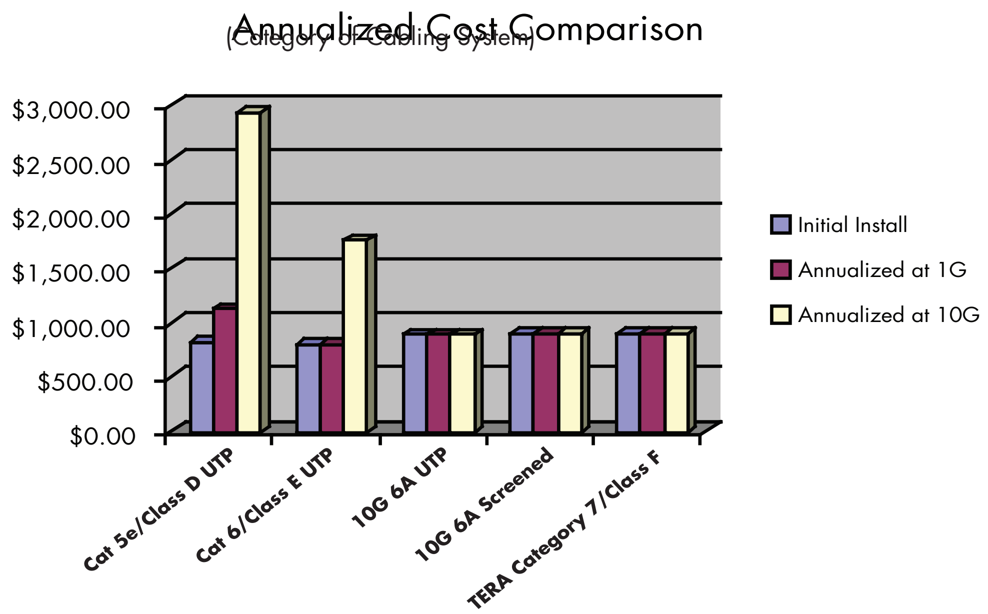
Each employee is also responsible for revenue. For this figure, we are estimating average hour revenue per employee. In utilizing the Fortune 1000 published revenue figures, we take total revenue and divide it by the number of employees and the hours worked (2080 per year) to obtain revenue per employee per hour (RH).

Total company revenue / total number of employees / hours worked per year = RH

Using Fortune 1000 data, average revenue equates to $132.40 per hour per employee or $3177.60 for 24 employees. Downtime is based on one user per cable. Data center connections such as those connected to servers would have many more users down while replacements occur. In the following table, downtime costs for lost wages/overhead and lost revenue per employee were accounted for in both category 5e and 6 systems. In the category 5e system add two hours of downtime per channel - one hour down to remove the channel and one hour down to replace the channel. For the category 6 system, downtime was calculated at 1 hour down for testing each channel plus 1 in 4 users down for 2 hours each to remove and replace non-compliant cabling channels over 55m.

24 Channels	TCO to support 10GBASE-T	Downtime Costs - Wages, Overhead and Revenue	TCO plus Downtime	New Annualized Cost of Ownership
Cat 5e/Class D UTP	New TCO applies	$7,435.07	$14,658.73	$2,931.75
Cat 6/Class E UTP	$9,543.21	$2,489.38	$12,032.59	$1,718.94
10G 6A™ UTP	$8,129.86		$8,129.86	$812.99
10G 6A F/UTP	$9,026.24		$9,026.24	$902.62
TERA® - Class F/Cat 7	$13,482.56		$13,482.56	$898.84

Any savings in downtime calculations (through work being performed after hours) would be offset by higher labor cost due to overtime rates for the installers. Testing time includes time to trace circuits. Keep in mind the average network has 1000 channels so these figures, once again, are very conservative. The following is a graphical comparison of the figures shown previously.



New 10G Cabling Installation Practices

Fill ratios are a significant change for 10G UTP systems. Due to the effects of Alien Crosstalk, a 40% fill ratio may be the maximum and other mitigation steps will be required as referenced in TSB-155. ISO 568-B.2-10 addresses the augmented category 6 systems and now allow for cable diameters to increase to 330 inches. In the calculations shown above, we have not included replacement of conduit or new core drills that may be required. Also bear in mind that categories of cable above 5e have larger cable diameters and may alter fill ratios for cable tray. Screened or Shielded systems will allow you to maintain a 60% fill ratio with a smaller cable diameter than augmented category 6, as the shield eliminates one of the greatest disturbers in 10G UTP system, which is ANEXT or Alien Near-End Crosstalk.

Copper vs Fiber to the Desktop

The idea of fiber to the desktop (FTTD) has been around for quite some time. Early proponents of FTTD sited problems with UTP systems and limited distances as their reasons for their recommendations. There are 10GBASE-X fiber applications, and in fact, those needing 10G bandwidth have had fiber options only for some time now. In evaluating copper versus fiber to the desktop, it is important to include overall network costs (including electronics), not just cabling costs.

Fiber components for 10G are expected to settle at a cost that is roughly 10x the cost of a gigabit port. On the copper side however, the cost will be about 3x the cost of a gigabit port or roughly one third the cost of a 10G fiber port. All PC's today ship with 10/100/1000 Mbps copper network interfaces. In order to use fiber to the desk, that investment will disappear and a new fiber card would need to be procured. The same cost differential applies. It is also noteworthy that the 10GBASE-T copper chips will auto-negotiate from 10Mbps up to 10Gbps. This means that one chip will be used for all network connections. It is far less expensive to mass produce one chip than several varieties. As 10GBASE-T chips begin mass production, they will begin to surface in server NICs, switch ports, etc.

Power over fiber is not a reality. There are several applications today that utilize Power over Ethernet (PoE) based on the IEEE 802.3af standard. 10GBASE-T is fully interoperable with power as an end-span solution (the power is supplied at the switch). The lack of ability to provide power over fiber may be limiting in some networks.

Fiber standards and lengths, have not been as stagnant as some people think. In looking at the chart below of supported lengths and types of fiber, from 100BASE-X to 10GBASE-X, it is easy to see that the similar replacements and/or remediation would be needed on some fiber channels in networks utilizing 62.5 micron fiber components for 10 gigabit applications.

Application	Wavelength	62.5 160/500	62.5 200/500	50 500/500	50 2000/500	SMF
100BASE-SX	850nm	300m	300m	√300m	300m	—
1000BASE-SX	850nm	220m	275m	550m	550m	—
1000BASE-LX	1300nm	550m	550m	550m	550m	5km
10GBASE-SX	850nm	28m	28m	86m	300m	—
10GBASE-LX	1310nm	—	—	—	—	10km
10GBASE-EX	1550nm	—	—	—	—	40km
10GBASE-LX4	1310nm	300m	300m	300m	300m	10km

Summary

For anyone responsible for selecting the right cabling infrastructure and who plans to occupy the premises for at least 5 years, this paper demonstrates that Augmented Category 6 (6A) or higher cabling systems are the most economical solutions, providing a solid return on investment. One should consider not only the initial costs, but ensuing follow on costs as well. Understanding the full lifecycle and industry trends will assist in your decisions. Remember that cabling represents only 5-7% of the overall network investment. It is expected to outlive most network components and is the most difficult and potentially costly component of a network to replace. There are few network investments more poorly made than the installation of a cabling system with a shortened lifespan that will require replacement sooner than economically forecasted.

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