Designing High-Performance Cabling Infrastructures for Post-Secondary Education

Berk-Tek®
A NEXANS COMPANY

legrand®
Ortronics

Colleges and universities are very much at the forefront of the digital revolution. Expectations are high and the necessity of meeting the academic and personal needs of students and faculty in the connected world makes campuses both an example of digital consumption and a laboratory for next-generation needs and solutions.

Campus as a Microcosm

Campuses are small cities—with all the needs of a city. Classrooms are the offices. Dorms are the residential section. A campus also has arts and sports in theaters, arenas, and stadiums, retail points of sale, security, broadcast studios, research labs, medical facilities, and even manufacturing. Plus, the campus has all the infrastructure of a city—mechanical and power systems, security systems, and so forth.

Campuses vary not only in size but also in services—medical school and research hospital rather than a student health center, supercomputers to support graduate research, or advanced scientific equipment to support research in nanotechnology, physics and other disciplines. Yet every campus supports the same basic requirements of community. And like any community, it requires network connectivity. Unlike the city, however, the network needs of the campus are more tightly integrated under an IT department.

Figure 1. A campus is the microcosm of a small city, with similar needs

Drivers for Post-Secondary Cabling Systems

Students and faculty expect to be able to connect throughout the campus, inside and outside, both wired and wireless. In addition, university networks require very high bandwidth with the growth of video distance learning, streaming video (such as in the classroom or the sports arena) large graphical files (such as in labs), student downloads and a growing need for expanding data storage usually requiring their own onsite data centers.

In addition to the bandwidth demands, there is an ever-growing IP convergence movement to attach unique applications and disparate systems, other than data, voice and video onto the Ethernet network. The success of Internet Protocol (IP) means that nearly all communication needs can be handled by a single network. Beyond standard data, other systems can run over an IP network: security, access control, building automation, video and television—if it can be done digitally, it can be transmitted over an IP-based network. While application will often be segregated, the fact remains that the prevalence of IP means there are more bits and bytes being transmitted and require greater data speeds.

Figure 2. Pervasive computing means being connected anytime, anywhere on campus

Bandwidth

The bandwidth needs on a campus are complex and varying. While an "ordinary" high-performance network will serve most needs, some departments may require higher bandwidth to accommodate transfer of enormous files and to allow high-performance computing. Computer-intensive research in physics and other academic disciplines often need cutting-edge connectivity. Similarly, a medical school needs to accommodate the transfer and storage of diagnostic images such as MRI scans. A broadcast school, with the need to edit and transfer large video files, has needs very different from a law school, where research is more "bookish." Large universities need all of the above.

A campus network is different in one important way. The "business" side and the residential side are connected in ways not found out in the community. A business does not share its network for the private and personal needs of employees. But student life resides on the campus network—and students place a heavy load on network resources, such as the following:

Social media—from Facebook and Twitter to YouTube and Flickr—are recent trends combining both pervasive connectivity and substantial network use. While the bandwidth demands of single transactions are modest, the volume of transactions is enormous.

Peer-to-peer file sharing—both for legitimate purposes and, more notoriously, for illegal downloading of music and video—is a significant bandwidth hog on many campuses. The same is true with student ftp servers, web servers, and multiplayer games. The network demands of students are heavy enough that most universities have resorted to bandwidth caps.

Storage

The volume of data that must be stored continues to grow exponentially. While storage costs per byte are miniscule, an enormous amount of information must be stored—and more importantly—accessed, backed up, and otherwise moved about on the network. Libraries are digitizing their collections, scientific research generates volumes of data, and the cloud is becoming an important application architecture. The bottom line for the network is obvious: storing and retrieving data requires high bandwidth.

Video: The power of the Internet has been harnessed for on-line courses, requiring real-time streaming and storage of audio and video. In addition, traditional brick-and-mortar classrooms benefit from the ability to bring the outside world—guest lecturers, video conferencing, and the like which will also become archived.

One-card systems: Many colleges and universities use debit cards for the majority of small transactions—including vending machines, cafeterias, student laundries, campus stores, and so forth. While such equipment must be connected to the network to track usage, demands on network performance are modest.

As schools move to a one-card system, tracking use becomes important to distinguish between use in the laundry room, library, cafeteria, or dorm room—and between access and transactions.

Security: Security is one of the fastest growing applications on campus. From access control and mass-notification capabilities to security cameras and blue light emergency phones, security networks need real-time access.

Recommended Best Cabling Practices

There are generic standards for buildings to address the architecture of the cabling system and recommend best practices for cross connects, cabling distances, cable and connector performance specifications, and all the other details for achieving a high-performance network. ANSI/TIA-568-C is the primary example of a generic standard whose recommendations form best practices for cabling systems.

A typical network in a typical business is largely a cookie cutter affair. With some exceptions, all work areas have the same network connectivity. Businesses standardize on providing the same connectivity to each office. K-12 schools similarly standardize classrooms. Likewise, retail stores often install the same network in every new store. Even variations tend to be small: four data ports instead of two. Generic cabling standards, like ANSI/TIA-568-C, rightly recognize that an extremely wide swathe of applications can beneficially adopt the standards.

Colleges and universities are unique in the variety of needs the network must support. On one hand, the cookie-cutter approach works, although many different cutters may be needed. For example, student dorms can all follow a basic pattern, providing each student with the same connectivity options. The same is true with classrooms, labs, libraries, common areas. Each has different needs, but each can follow a standard set of rules to meet those needs. On the other hand, special requirements must also be met. While most end users need only 54-Mb/s wireless or wired Fast or Gigabit Ethernet, there still may be reasons to provide 10G connections beyond the backbone and even to the desktop.

Cabling Choices

As a general best practice, install the best grade of cable available. Experience shows that network capabilities evolve, bandwidth needs grow, and storage requirements increase. For example, streaming video movies and television over the Internet today is a real alternative to cable TV on a college campus. Installing a cabling system to meet only today's needs may mean a network that won't meet tomorrows.

Cable Type	Cable Grade	Performance (Min.)	Cabling Distance (m) @ Data Rate	
			1 Gb/s	10 Gb/s
Twisted-Pair Cable	Cat 5e	100 MHz	100	X
	Cat 6	250 MHz	100	
	Cat 6A	500 MHz	100	100
Optical Fiber**	OM1 (62.5/125)	200 MHz	220	X
	OM2 (50/125)	500 MHz	300	X
	OM3 (50/125)*	2000 MHz	1000	300
	OM4 (50/125)*	4700 MHz	1040	550
	OM 4+ (50/125)*	4900 MHz	1210	600
Coaxial Cable	Series 6	3 GHz	N/A	N/A

Figure 3.

*Laser optimized

**Performance specs for 850 nm wavelength

Backbone Cabling

Single-mode fiber: single-mode cable is used for interbuilding connections, where the combination of long transmission distances (up to 40 km) and high bandwidth allows even large campuses to be networked.

OM4 fiber: OM4 multimode fiber is suited to backbone cabling within buildings.

For fiber, flexible options also exist in achieving different levels of performance. The preferred choice is 50/125-μm laser-optimized fiber, which is designed for optimum use with low-cost electronics. Laser-optimized fiber is available in two performance levels, OM3 and OM4. The fiber bandwidth translates into the allowable distances the cable can be run. While allowable distances are two to three times longer for Gigabit Ethernet than for 10G Ethernet, remaining within 300 m recommendations of TIA-568.C when planning and only going longer distances in special cases is a good practice.

Fiber optic cables can be run either as pairs or as multifiber array cables. Multifiber cables terminated with industry-standard MTP®/MPO array connectors simplify use of fiber in the network. The cables significantly reduce congestion in pathways, provide the highest port densities (12 fibers in a 0.5 x 0.3-inch area), and simplify system design, installation, and management. While fiber ribbon cables are popular for array connections, new reduced-diameter cables, such as Berk-Tek's MDP (Micro Data Center Plenum) cable, are setting a new standard in convenience. Cassette modules, like the one in Figure 4, provide an easy breakout from the array cable to individual ports.

Figure 4. Modular fiber cassettes make it easy to transition between array backbone cables and fiber pairs.

Horizontal Cabling

OM3 or OM4 multimode fiber: fiber has two main uses in horizontal application: to extend connection distances beyond the 100 m of copper cable and to provide a noise-immune cabling medium in areas subject to high levels of EMI.

Cat 6/Cat 6A UTP/FTP: for data connections. Category 6A UTP/FTP is the highest category of cable recognized by 802.3C and will support data rates as high as 10 Gb/s over 100 m. Unshielded UTP suffices to most applications—dorms, classrooms, libraries, and so forth. Consider FTP where levels of EMI may be higher or where sensitive lab equipment might be affected by emissions from the cable.

Cat 5e UTP/FTP: for building automation, security, and similar low-bandwidth requirements.

The choice of Category 6A cable over Category 6 is a means of ensuring you are ready for future needs and capable of migrating to 10G to support future networking and bandwidth needs. The main distinction between Category 6 and 6A is bandwidth. Bandwidth is specified by industry standards.

Vendors of high quality cable typically offer cables that exceed the bandwidth specified in ANSI/TIA-568-C, which translates in additional performance margins—or headroom—in the cable's performance. Figure 5 compares Category 6/6A offerings from Berk-Tek, a Nexans Company, to demonstrate how cables can exceed the basic performance requirements of standards.

Cable diameter can also be an issue in routing a large number of cables through crowded pathway and spaces. Cable designers must manage tradeoffs between minimizing cable diameter and achieving performance goals. (Note that while higher category cables have larger diameters, there exists difference among vendors.)

Cable	ANSI/TIA/EIA-568 Bandwidth (MHz)	Usable (Specified) Bandwidth (MHz)	Diameter	
			Patchcord	Plenum
LANmark-1000 Cat 6	250	250	0.224	0.226
LANmark-2000 Cat 6	250	400	0.247	0.220
LANmark-10G2 Cat 6A	500	625	0.290	0.300

Figure 5. Cables offering performance headroom provide a better margin in performance.

PoE and Hybrid Cables

Power over Ethernet (PoE) delivers power to devices over the copper network data cables. The obvious advantage is to eliminate a separate power feed, which is especially useful for remotely situated devices such as wireless access points, security cameras, access controls, building automation devices, and even VoIP phones. The original version of PoE can deliver up to 13 W, while the more powerful Type 2 offers 25 W.

PoE can be deployed as an end-point device, where the power is sourced from the port of network equipment, and as a midspan device, where power is injected at some point in the cabling system.

PoE drives the use of copper cabling. If fiber connections are required at the device, hybrid fiber/copper cables are available to deliver the data over the fiber and power over the copper conductors. Hybrid cables are useful when connection distances exceed the limits of copper data cables.

Security cameras are a good example of such an application. If the camera location is further, such as in a parking garage or for blue light stations, there needs to be an additional cross connection with additional switches and active components. But, the structured cabling standards allow for a maximum of three cross connects between the ER and end use. Therefore, extending the distance to remote locations, such as a pole on a parking lot, along fences or even in transit routes, it is not feasible to use twisted pair cabling.

Optical fiber is the choice to extend the distance. In addition fiber is impervious to heat, EMI, RFI and is a more stable transmission. Since the IP cameras operate off of RJ-45 ports, media converters must be deployed at each end to perform electro-optic conversion between electrical signals and optical signals. PoE media converters perform the opto-electric conversion by injecting DC power over the UTP cable. With this solution, an additional 100 meters can be added.

PoE extenders support even longer distances where local power for the media converters is not feasible or accessible. For example, Berk-Tek's OneReach PoE Extender System is a hybrid solution running data/ over the optical fiber and power can run over copper conductors. Because the cable carries low-voltage power (up to 25 W) it is defined as a Class 3 copper cable with fiber (through the NEC codes). The stranded copper conductors are 12 AWG or 18 AWG and coupled with either tight-buffered or loose-tube multimode optical fibers.

The powered media converter, or midspan power injector located in the TR injects both the power and the data from the active equipment – the fiber switch port and the copper power supply unit. The composite cable assembly attaches to the injector through fiber LC connectors and screw terminals for the copper/power conductors. Distances up to 3850 ft. for PoE and 2500 ft. for PoE+ between media converters can be achieved. In addition, you can run the UTP an additional 100 m (328 ft.) from the media converter to the camera. At the camera end, multiport media converters are also available, although connection distances are shorter since multiple cameras must be powered.

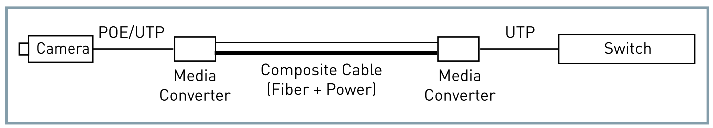

Figure 6. OneReach PoE Extender System is a convenient way to power remote devices at distances up to 3850 ft.

Wireless: Thin versus Thick

Mobility is important to both students and faculty, and mobility means wireless. Wireless should support 801.11b/g/n. Make sure there are enough access points to provide seamless coverage and to handle present and anticipated future loads. A site survey helps determine the number and location of APs to meet needs.

Using thin APs allow easier management of the wireless system. So-called thick APs are full-featured units storing all settings locally. Local storage means that, in the event of a change, each access point must be individually changed. Thin APs put the intelligence in a central controller in the TR so that all APs can be managed from a single point. What's more, multiple controllers can be managed as a group.

A data outlet should be provided at each AP. A power outlet may also be necessary, although many APs can be powered by PoE.

Outlets

Work area outlets should be generously allocated. It is better to have an extra outlet or two for future needs instead of a shortage. Even if wireless is expected to be the primarily means of network access, wired connectivity is still important. Outlet should be clearly color coded by function.

For student housing, the following is a recommended minimum requirement:

- One data outlet per pillow
- One voice outlet per room
- Coax for CATV (or additional data outlet for IPTV)

Common areas should have at least one outlet for every 6 feet of sitting space.

Outlets in the work areas should be clearly and easily identified by function. Since some areas will contain many separate networks—public, educational, television, phone, security, etc.—fast and easy identification is critical. The outlet jacks themselves are available color coded as are snap-in icons (Figure 7). Visual identification is essential for end users. For network administrators and technicians, additional identification for purposes of network administration is recommended.

Figure 7. Color-coded multimedia outlets allow easy port identification.

Telecommunications Rooms

Be generous in sizing an equipment room or telecom room, allowing for growth.

Racks, patch panels, and fiber-management hardware should offer great convenience in managing the cables. This includes such issues as supporting cable vertically in the rack, limiting bend radii, eliminating any stress on the point of connection, and enabling easier moves, adds, or changes (MACs).

The cabling density in campus applications and high-density servers mean that racks need to accommodate both more equipment and more interconnections. A Mighty Mo® 10 rack from Legrand|Ortronics, for example, can support up to 1340 network ports. It also allows up to 48 patch cords per vertical rack unit on each side to ensure availability of cabling without clutter or mess. Figure 8 shows a typical high-density installation.

Figure 8. Effective cable management in high-density configurations must prevent stress on cables and connectors.

In designing for high-density configurations, select racks and cabinets with generous cable-routing capabilities on both the front and the back. Deep management channels not only accommodate a larger number of cables, they make them easier to manage—such as tracing an individual cable or adding new cables.

Choosing the right rack and cable pathway components can save money in the long run. Make sure racks and trays can handle future weight requirements. A fully loaded enterprise-level switch can weigh 1600 pounds. While a two-post rack might be fine for patch panels, a four-post rack is the better choice for equipment.

The ER serves as the main distribution point for the building and as the "interface" with the rest of the campus. Buildings have one ER. The ER contains the building's main cross connect, which provides backbone connections to the TRs.

TRs provide the transition between backbone cabling and horizontal cabling to end users. TRs should be placed in the same location on each floor—stacked on above the other. Large buildings may require two or more TRs on each floor.

Interbuilding runs should be housed in conduit. Because of distances, multimode fiber is preferred for runs of 300 m and single-mode for longer runs.

Upgrading Existing Infrastructure

In new buildings, following best practices is easier since the cabling infrastructure can be accommodated during the planning stages. Existing buildings also need to be upgraded to maintain required levels of service. Surface-mount raceways (Figure 9) are well suited to providing both power and data outlets in a convenient, sturdy form. Today's raceways are more attractively designed, accommodate a wide range of cabling/outlet types, and can be installed at any height horizontally or vertically. Given that many existing buildings have concrete or cinderblock walls that make behind-the-wall cabling impractical or impossible, raceways are cost effective and easy to use.

Figure 9. Raceways

Look to the Channel System, Not the Parts

In the end, it is not the performance of individual components that is important, but the end-to-end performance of the components working together—the channel. The aim of the channel is to achieve zero bit errors caused by the cabling system.

Buying a warranted cabling system, versus combining parts and pieces has three distinct advantages: (1) it ensures performance headroom, (2) it brings a healthy warranty (such as the 25 years for NetClear® systems) that guarantees the system will meet performance goals and applications assurance, and (3) it gives you peace of mind by having a single source ready to support the cabling system.

Look for systems that have performance claims verified by an independent testing agency. The system should provide adequate headroom above the standard. Headroom equals peace of mind. Over time and many MACs, inadvertent tight bends, or rough handling of patch cords, the cable system's performance can degrade somewhat. Headroom is the extra margin that ensures your network keeps peak performance for years to come.

A system-level approach does not mean a single vendor who offers everything. It means that all the components are designed and tested to optimize performance. The NetClear solution, for example, is an alliance between Berk-Tek, a Nexans Company, for cable and Legrand|Ortronics for connectors and cable-management hardware. A close partnership between the companies allows each to lend its expertise in achieving system performance and providing systems with the guaranteed headroom shown in Figure 10. The headroom is the guaranteed performance above the standard.

NetClear System	Headroom (dB) Above Basic Cat 6	
	Crosstalk	Return Loss
GT2 (Category 6)	5	3
GT3 (Premium Category 6)	8	6
GTX (Category 6A)	12	6

Figure 10. Cabling systems should provide generous headroom and zero bit errors in the channel.

Cabling systems should provide generous headroom and zero bit errors in the channel.

Buy or Make? Ordering pre-terminated cable assemblies offers products that have been factory made and tested. While field termination is possible, it has several drawbacks. The higher the performance level of the cable, the more important correct termination procedures for connectors becomes. Once terminated, each cable should be tested to characterize its performance. Cable assemblies eliminate these needs. While patch cords are usually bought as assemblies, backbone and horizontal cables can also be specified and installed as assemblies. The biggest drawback is that you need to be able to confidently specify lengths. Coming up a few inches short because of the need to route around an unforeseen duct is obviously a problem. Careful planning is mandatory.

Berk-Tek, A Nexans Company
132 White Oak Road
New Holland, PA 17557
Tel: 800-BERK-TEK; 717-354-6200
Fax: 717-354-7944
www.berktek.com

Legrand|Ortronics
125 Eugene O'Neill Drive
New London, CT 06320
Tel: 800-934-5432; 860-445-3900
Fax: 860-405-2992
www.legrand.us/ortronics