Color-Coding Considerations for Identification of Horizontal Cabling

Introduction

The Ethernet network is becoming ever more pervasive: as well as being dominant in Smart Data Center and enterprise applications, we are seeing increased deployment of Ethernet in Connected Building and Industrial Automation applications. As a result, horizontal cabling pathways are often extremely packed with network cabling, and it is extremely difficult to easily identify one particular network cable in the pathway from another, or to know what application it is being used for.

For example, in the data center there are many situations now where the sheer volume of cabling and number of cables will determine acceptable cabinet width. The typical cabinet for a high performance Smart Data Center will incorporate separate channels on either side of the main 19 inch area for installation of rack mounted equipment to accommodate and allow effective management of the cabling required for equipment interconnect.

In the case of Connected Buildings, technology is trending toward consolidation of manufacturer specific, proprietary communications protocols in the form of common standards based protocols. The flexible and low cost nature of Ethernet networking protocol makes this the likely eventual leader even among protocols based on common standards. Networking technology deployed in Industrial Automation applications is also in a similar state of change where, for many of the same reasons seen in the Connected Building arena, technology is driving networking infrastructure to lower cost, high speed, flexible and standards based types and Ethernet is again expected to play a major role. Other standards based communications protocols are widely deployed, such as Modbus TCP/IP, Profinet, etc, but Industrial Ethernet in the form of Ethernet/IP continues to gain adoption.

This Technology Brief explores aspects of the color-coding of the exterior jacket of network cabling – and copper cabling in particular –as part of a physical layer solution based on the Unified Physical Infrastructure^{SM} (UPI) approach to align, converge, and optimize core business systems. The effectiveness with which IT staff can carry this out is dependent upon the design and identification guidelines that are in place in the IT area along with how well the installation practices to support this have been carried out. Implementation of a suitable scheme can result in a number of benefits, including the following:

- Easier and more accurate installation reducing overall installation time
- Improved routing of cabling within the pathway since similar color cables would tend to be installed together
- Improved identification of cabling at a future time will be useful when Moves, Adds and Changes (MACs) are necessary
- Reduced time to trace and troubleshoot faults, carry out repairs thereby improving service levels
- Improved assurance that critical cables will not be inadvertently removed – as an example, the IT manager institutes a policy that junior network technicians are not permitted to install or remove red patch cords, and that where such action is required, it needs to be carried out under direct supervision
- Improved accuracy and reduced time to carry out audits or verifications of data center assets

Although this document does not make specific recommendations for an actual color-coding scheme, it explores the many factors that need to be taken into account if a color-coding scheme is adopted, especially for copper cabling. Ultimately the IT staff at a particular site likely will make the specific choice for the cabling infrastructure color coding scheme.

Barriers to Past Adoption of Color-Coding Schemes

It is interesting to explore reasons why a color-coding scheme for copper network cabling has not been widely deployed or even mandated by means of an applicable standard. Although there is a widely observed color-coding scheme used for optical fiber cabling, for example see ANSI/TIA-568-C.3, "Optical Fiber cabling Components Standard" and ANSI/TIA-598-C, "Optical Fiber Cable Color Coding", there does not appear to be an accredited, de facto standard or even a recognized recommendation of a color-coding scheme for the exterior jacket of copper cabling.

Different cabling industries (for example, power and control) do follow color-coding standards, but many of these apply in different situations and in different parts of the world. Also, a variety of factors exist as barriers to consistent color coding schemes:

- Cost (e.g., colored wire cost vs. white; standard color versus non-standard)
- Different tints or tint variations in different production lots
- Availability of the cable / delivery
- Demands of the cable suppliers on minimum order quantity
- Volatility to maintain, i.e. permanent (jack) vs. removable (color band)
- Color code intuition (e.g., red patch cord for firewall)
- Complexity/layering of color-codes (i.e., multiple color-codes applied)
- Process of adding a new color

- Changing the meaning of a color (e.g., reconfigured manufacturing)

- Color blind employees

- Color fading, dust, painted over, etc.

- Legacy/brown field (i.e., not easy to change field wire color)

- Easy to find, up-to-date color-code documentation/legend

- Easily accessible color code features, e.g. multi-colored block-out

- Different groups in the installation having different areas of responsibility – e.g. IT and facilities

- Differing colors between different manufacturers

- Additional labeling on jacket (i.e., flame and smoke performance)

- Potential for difference between global identification standards, complicating consistency between local / global installations

Options for the Basis of a Color-Coding Scheme

Most discussions of cable identification tend to focus in the areas of connections of the horizontal cable to jacks, through patch panels and following patch cords and aided by clear and effective labeling. However, there are times when identification of horizontal run cabling is useful or even necessary. Options as to how a color-coding scheme could be devised include (1) data rate, (2) cabling media type, (3) location throughout the facility, and (4) application type.

Data Rate (e.g. 100 Mbit/sec, 1 Gbit/sec or 10 Gbit/sec)
Twisted pair copper cabling, unshielded twisted pair (UTP) or shielded twisted pair (STP), is used widely as the medium of choice when designing and installing network connections between equipment at data rates of up to 10 Gbit/sec and when the channel length is less than 100 meters. Fiber can also be deployed, but due to additional transceiver costs tends to be deployed in those applications requiring longer cable lengths, or when the cabling is routed through an area that is subject to high levels of electromagnetic interference (EMI). These two situations do tend to occur more frequently in industrial networks, making use of fiber potentially more attractive for consideration in these cases.

The main drawback of using data rate as a guide to color-coding is that a cable supporting a higher data rate is backwards compatible to the lower data rate. For example a 10 Gb/s cable assembly can support a lower data rate (e.g. 1 Gb/s) and there will be many times when the higher data rate cable could be pressed into service for lower data rate use. In those cases, the immediate needs of the data to be supported would probably override adherence to a color-coding scheme, limiting if not voiding the usefulness of such an approach. Indeed, at this time most IT managers are actively looking to deploy a 10 Gigabit networking infrastructure while supporting lower data rates. The 10 Gb/s infrastructure is installed as a means to future proof for technology updates that will be made in future years.

Cabling Media Type / Properties

This option represents the broad cable type, for example UTP one color and STP another, or maybe plenum in one color and riser in another, or whether the cabling can support Category 5e, Category 6 or Category 6A transmission, as examples. Interestingly, it is on this basis that the color coding for optical fiber is centered on – broadly for enterprise use, OM1 / OM2 jacket is orange, OM3 / OM4 jacket is aqua, and OS1 / OS2 jacket is yellow for ease of identification.

At first sight, this option does look like it could adapt well to technology developments. As far as can be seen, if a new technology cable would be deployed there are likely to be suitable, separately identifiable colors for use in a scheme. The main concern, however, is likely to be that in many installations, there is frequently a dominant use of one cabling type, for example Category 5e UTP from the edge or access switches to the work area, and edge switches to the server nodes. In this case, there would be mainly a single color identifying the cable type used, but of little use to indicate anything else.

Location Throughout the Facility

Alternatively, different color-coded cable could be used to denote cabling that would lead to a different part of the installation or perhaps to different floors. This does have some benefit and merits consideration in some installations. However, depending on the particular situation, some areas of the installation may have areas of dense cabling, and the use of just one color in this area would again reduce the usefulness of the scheme.

An example of how this could be implemented is in a co-location data center facility where external customers require assurances that their services are supported in just one area of the installation. Here, the IT manager can more readily assure the client of this when audits or compliance inspections are carried out.

Application Type

For this option, a scheme is developed whereby different colors of cabling identify the types of applications that are supported over the cabling. As an example, taken from the Industrial Automation environment, it is often advantageous to separate the Ethernet network for the enterprise from an intranet that might be used for the manufacturing floor network, yet both networks will need to access some common information from the same server. A common technique employed in these cases is to set the switch up together with a firewall or firewalls to create a de-militarized zone that effectively prevents the intranet from being exposed to potential harm from the enterprise internet and vice versa. In this case, the use of different color-cabling representing connections to the internet, intranet and common servers would be particularly useful. Another example might be where cabling used from an aggregation switch to the edge switch might have a different color from cabling used from the edge switch to the server node. Alternatively local area network (LAN) cabling might have one color code for the main runs whereas the redundant cabling would use a different color.

Here the key concern would likely be that a wide variety of applications exist in the typical networked environment, and different organizations might support completely different applications. Depending on how granular the scheme is required, there could well be more applications than color types that are practical and readily differentiable in the typical installation. Additionally, a concern would be to ensure that the cabling color scheme devised could anticipate future application developments. For example, five years ago would those responsible for devising the standard for the color scheme have predicted the rapid development of the standard and deployment of consolidation storage and local area network (LAN) traffic supported by Fibre Channel over Ethernet (FCoE), if it was felt useful to have a color-code to designate consolidated traffic versus separate storage or LAN traffic?

The benefits and disadvantages of the four cabling color coding options presented, i.e. color-coding scheme based on a) data rate, b) cabling media type, c) location and d) application type can be summarized in the following table:

Color-Coding Option	Data Rate	Cable Properties / Performance	Cable Location	Supported Application
Upsides	- Very intuitive options (e.g. 10 Mbps, 100 Mbps, 1Gbps, etc)	- A reasonable number of options (fiber, copper, different category cables, UTP, STP, etc.)	- Has some potential especially in areas of shared / co-location facilities	- Easy identification of different cabling by different persons, (e.g. LAN, storage, etc.)
Downsides	- Confusion: Cabling capable of supporting a high data rate can also support a lower data rate, so confusion may result if high performance category cabling is repurposed in future for other links	- Redundancy: Cable jacket is most likely already marked with text describing properties / performance data - Does not convey additional information beyond text-based marking	- Cabling density: Some areas within the facility can require a high number of cables. Not having some way to identify cabling can diminish the usefulness of the scheme	- Too many applications versus practical cable color options - Applications can develop in a small number of years from zero to dominant deployment

Despite these challenges, Panduit has found that most enterprises gravitate toward cabling color schemes based in some way on application type. This is most likely due to the ability of IT managers to map available cabling infrastructure colors to general logical application architectures. These schemes are not currently based on mandated standards, but rather follow guidelines, best practices or recommendations, and are devised by the particular enterprise's staff to fit their unique situation. Even then, a scheme implemented in an installation may require many caveats and exceptions, especially if being incorporated into a legacy or brown field installation. Coupled with this recommendation is the footnote that the IT staff for the installation would need to ensure that the scheme is adequately communicated to staff and installation contractors alike.

Given the general favor that color-coding techniques based on application have found with IT stakeholders, the remainder of this brief will examine some examples of such deployments.

Example Color-Coding Schemes Based on Application Types

Panduit believes that it is beneficial to the networking industry to provide information and options for solutions to support a color-coding scheme for the cabling infrastructure by identifying ways in which the scheme can be supported in the user application. Other options over and above that of the color-coded jacket will be identified, and these give the user important options for handling special situations, or providing a higher level of granularity for more individualized applications.

The following is a list of some applications that are encountered in many types of data center, industrial Ethernet and connected building scenarios. Cabling colors may be assigned to identify and keep separate various core business systems at a higher level (i.e., compute, communication, security), or may be used to denote various subsystems and/or individual applications:

- Different VLANs
- Building, Room, Floor – i.e., To Location
- Active or Inactive cabling
- Network Speed
- Network A/B
- Different zones – e.g. manufacturing, DMZ, enterprise
- Power Over Ethernet (PoE)
- POU A/B Circuit (White/Black)
- Cabinet device connection, e.g. Firewall, server, switch
- Function, e.g. Data, Phone, Printer, Fax, Barcode, etc.
- Fiber Type
- Shielded/Unshielded
- Safety

- Organization, e.g. QC, Maintenance, Accounting, etc.
- Mfg. Process, e.g. paint, bending,
- Mfg. Equipment, e.g. molding, extrusion, assembly, etc.
- Interconnect type – Ethernet / Fibre Channel / InfiniBand
- Wireless LAN – cabling to access points
- Analog / control data / low voltage / telco
- Criticality of data / policy decision process
- Managed ports
- Interconnect application – LAN, SAN / NAS, IPC
- Converged cabling – LAN / SAN {FCoE}
- Tier level in, e.g. Cisco switching architecture – Access – Aggregation – Core

Example 1: Panduit World Headquarters

The following is a list of the color-codes for the exterior jacket of copper cabling that were adopted at Panduit's new World Headquarters that was opened in March 2010. In this building, Panduit had the benefit of this being an entirely green field site, so that a color scheme could be devised to be used at the start of the project, and not be concerned with challenges such as prior installations or existing cabling.

- Blue – Primary server connection
- White – Secondary server connection
- Green – Analog phones
- Yellow – WAP connection
- Red – Security connection
- Orange – Visitor VLAN

Figure 1 shows color-coded copper cabling bundles leading from server cabinets. In many installations, the cabinet will contain in excess of 40, one RU profile servers. The server-to-switch connections are very often configured for two separate connections, referred to as primary and secondary connections (alternatively main and redundant). In this example, cables associated with the main connection are color-coded blue, and those for the redundant connection are color-coded white. Adherence to good labeling practices in the vicinity of the connections to equipment is followed to aid identification of specific cables at a later time. Color-coded hook and loop ties neatly support cable bundles without pinching and potential performance degradations associated with often used nylon cable ties. These cables will be connected to the patching fields for the servers within the cabinet.

Figure 1. Color-Coded Server Cabinet Cabling Bundles in Panduit World Headquarters

It can be seen in the figure that the different colored bundles are directed in different directions as they enter the overhead cabling pathway; the white bundles are directed to the left of the figure, the blue bundles to the right. This is a practice often followed in high availability type Smart Data Centers, where cabling is led in different routes to give redundancy in these important cabling trunks. The overhead pathway extends not only along the length of each of the server and switch cabinet rows, but also between these rows at both ends to allow cabling to be routed in this manner.

Figure 2 shows the rear view of the patching fields for the switch. 192 cables each in white and blue enter the patching field. Patch cords are used on the reverse side of the cabinet to connect to the switch.

Figure 2. Switch Cabinet Patching Fields

Example 2: Industrial Automation Application

As Ethernet steadily marches into the shop floor, Industrial Ethernet is becoming increasingly adopted following the specifications released by the Open Device Vendors Association (ODVA). One of the interesting aspects of the industrial network is the critical need to separate the manufacturing network from the enterprise network. Serious damage could result in enterprise users reaching by accident or design the manufacturing network. Machine performance could be adversely affected, damage to plant could result, and lives could be put at risk.

In order to prevent this scenario from occurring, the industry makes use of firewalls to set up a de-militarized zone (DMZ) which prevents all but authorized access. There is a need for the enterprise network and the manufacturing network to use common information, for example, certain servers, so it is common to see connections from the firewall going to the enterprise network, the manufacturing network and the common server field. In this example, it would be very desirable to adopt a broad color-coding scheme to allow quick and easy identification of critical cabling. The color-coding serves as a good way to quickly check the validity of connections made either at the time of original installation or at the time of MACs made at some future date.

An example that has been devised within Panduit uses the following colors for copper UTP cabling (see the lower patch panel in Figure 3), with different groups of colored cabling connected into the patching field for the DMZ. The color red was intentionally not chosen, as this is often a color assigned to systems directly relating to the safety of personnel (i.e., fire / life / safety).

- Blue – enterprise network
- Yellow – DMZ
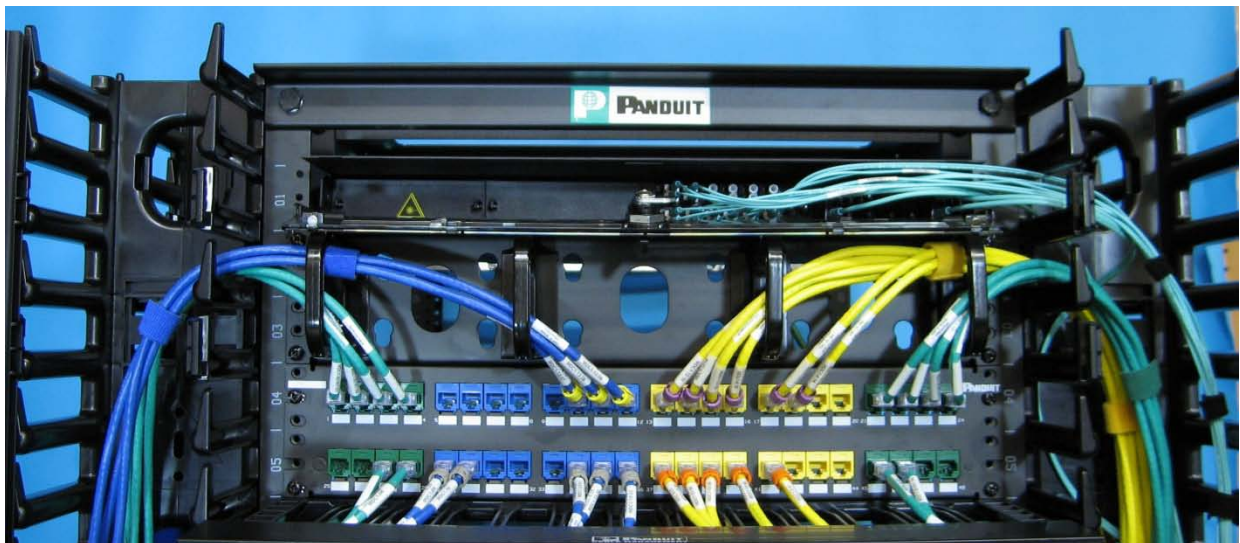- Green – manufacturing network

Figure 3. Demonstration of color-coded network cabling in an Industrial Automation solution.

Color-Coding Beyond Cables

This technology brief has so far made several points as to how a copper cable color-coding scheme might be set up and implemented. Two key points are (1) the cabling infrastructure color-code often denotes the application, and (2) the best color-coding scheme stay broad enough to cover some high level applications and/or business systems (i.e., compute, communication, and security).

In most real life situations, IT team members will require coding along with other identification methods that can be used to designate more specific applications, and will require ways to execute this if necessary. A significant number of options that can be used as a supplement to or even in place of, depending on the color-coding used in a legacy installation, the broad application based color-coding scheme outlined. Some of the additional methods used by Panduit that leverage a color scheme to organize horizontal network cabling include:

- Field wire terminated to the jack module (redundant network and safety consideration)
- Jack module color
- Labeling solutions
- Jack icon
- Modular plug
- Patch cord
- Color Band
- Block-out (Active/Inactive colors)
- Hook & Loop/Cable Tie
- Color-coded labels
- Different parts of the network deployed in different Enclosures
- Cabinet/Racks Duct/raceway
- J-Hooks
- Keyed jacks – colors and keys

The use of additional identification aids also aligns with the way that optical fiber is color-coded. From above, we note that the exterior jacket of optical fiber has already been specified through ANSI/EIA standards and is based on the property of the medium rather than the application into which it is used.

These additional identification solutions from Panduit will give the optimum overall color-coding scheme to both fiber and copper networking cabling. Interestingly, the most recent update of the ANSI/EIA-568-C.3 for optical fiber components was released in 2008 and includes recommendations for the color-coding of the connector strain relief, housing and adapter to support installations when color is used to identify fiber types.

Conclusion

This Technology Brief explores how a color-coding scheme for network cabling might be used to differentiate the use of one part of the overall network from another. It is the purpose of Panduit as a networking infrastructure leader to provide tools in the form of products and solutions to the IT staff by which the coding scheme can be effectively devised, configured, deployed and managed.

Panduit suggests that the color-coding will likely be particular to each user installation almost on a unique case by case basis, but where it is possible to adopt it that the scheme should be application based, and only a broad scheme covering the main applications be instituted. A wide and flexible range of additional items are available in a variety of colors, that can be used to give additional depth of detail and serve as supplements to the main network cable jacket color-coding adopted. The benefits realized by incorporating a well designed color-coding scheme will significantly improve the management of the network resulting in increased business efficiency and service levels.

About Panduit

Panduit is a world-class developer and provider of leading-edge solutions that help customers optimize the physical infrastructure through simplification, increased agility and operational efficiency. Panduit's Unified Physical Infrastructure (UPI) based solutions give Enterprises the capabilities to connect, manage and automate communications, computing, power, control and security systems for a smarter, unified business foundation. Panduit provides flexible, end-to-end solutions tailored by application and industry to drive performance, operational and financial advantages. Panduit's global manufacturing, logistics, and e-commerce capabilities along with a global network of distribution partners help customers reduce supply chain risk. Strong technology relationships with industry leading systems vendors and an engaged partner ecosystem of consultants, integrators and contractors together with its global staff and unmatched service and support make Panduit a valuable and trusted partner.

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