Structured and Point to Point Network Cabling for Industrial Automation

Introduction

Industrial automation systems are undergoing dramatic transformations that require businesses to adopt new strategies for industrial Ethernet. With the transition to Ethernet connected controllers, computers, high speed motion control, cameras and power electronics, past industrial network practices may not be applicable, therefore new approaches are necessary. Every day, 160,000 new industrial Ethernet nodes are connected[1]. To address this migration, the design, specification, installation and testing of Ethernet network cabling systems need closer examination.

Ethernet cabling in manufacturing environments is deployed using two distinct methods:

Structured Cabling	Adopted from IT in the enterprise down to the manufacturing machine or process equipment	• Copper or fiber cable terminated with connectors • Connected by patch cords to active equipment
Point to Point Cabling	In use for over 25 years in manufacturing to connect proprietary control networks, and is now migrating to Ethernet connecting devices	• Copper or fiber cable with field terminated connectors • Directly connected to device or machine ports

The purpose of this document is to describe structured and point to point cabling, as used for Ethernet deployments, and identify the considerations associated with using each cabling method.

Structured Cabling

Structured cabling is a planned cabling system that systematically lays out the cable management necessary for communications, including voice, data, video and control for today and the future. Structured cabling consists of eight standardized subsystems:

1. **Entrance Facility -** Represents the location where external communications enter the facility. This serves as the demarcation point between the standards and regulation requirements for outside plant vs. inside plant.
2. **Equipment Room (ER) or Data Center (DC)** - Serves as the top level of the enterprise/building network and may link to higher level corporate network and business system tiers.
3. **Enterprise Telecommunications Rooms (TR)** - Houses horizontal and backbone cable terminations and distribution switching. Cross-connections of horizontal and backbone terminations using patch cords to extend services to telecommunications outlets may be performed here.
4. **Enterprise and Factory Riser (Backbone) Cabling** - Connects the enterprise ER/DC to enterprise TRs and to the Industrial TR (Micro Data Center).

5. **Enterprise Horizontal Cabling** - Connects the enterprise TRs to zone cabling systems, Intermediate Distribution Frames (IDFs) or wall outlets.
6. **Micro Data Center** - A specialized Telecommunications Room (TR) that provides a logical separation of equipment and facilities between the enterprise and factory networks.
7. **Work Area or Cell Horizontal Cabling** - Connects the micro data center to the factory outlets, zone cabling systems, control panels, consolidation points and zone cabling (routed via trays, conduits and J-Hooks).
8. **Enterprise and Factory Outlets/Cabling** - Work area components are from the outlet of the horizontal cabling to the enterprise or factory work area equipment (connected with equipment or 'jumper' cords).

Figure 1 highlights these cabling subsystems in a combined enterprise and industrial plant scenario. External communications (typically run over fiber) arrive at the enterprise entrance facility, where a demarcation patch panel or splice vault separates the cable plants (1). Multi-fiber cabling then connects this demarcation to patch panels in the Equipment Room/Data Center (2) and between the Equipment Room/Data Center and the Telecommunications Rooms (3). Horizontal cabling (typically copper UTP) connects the enterprise telecommunications room to the office work area outlets (4). In this scenario, backbone cabling from the ER/DC connects to the factory floor control room micro data center which includes a De-Militarized Zone (DMZ) that provisions logical and secure separation between the two networks (5). Horizontal cabling connects the micro data center to zone enclosures, IDFs, control panels and the factory work area (6). Factory work area cabling downlinks run from the zone enclosure or control panel to provide flexibility for frequently changing connections to devices and manufacturing equipment ports (7). For the office work area, patch cords run from the work area outlets to workstations, phones, printers or other network devices (8).

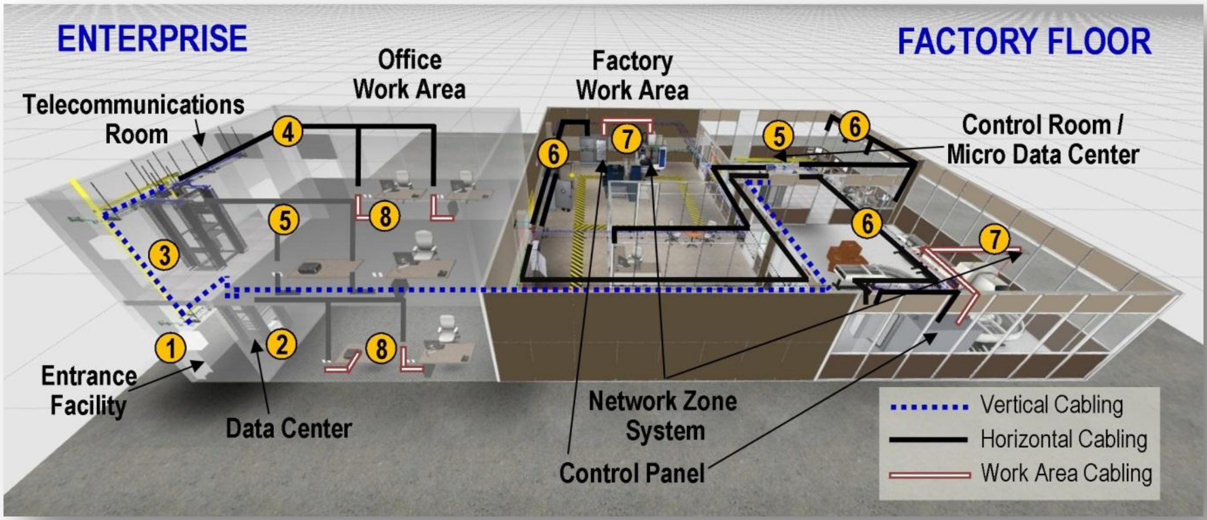

Figure 1. Structured Cabling Block Diagram.

A standards and structured based approach to the physical industrial network to implement a structured cabling methodology can reduce performance and security risks from the moment the logical network is defined. Taking this approach to factory floor physical design can be the critical factor in avoiding poor infrastructure, network sprawl, troubleshooting challenges, and safety and security issues.

Standards

Structured cabling design and installation are governed by a set of standards that specify wiring the different premise types for communications and controls using various kinds of cable, most commonly four pair, twisted pair copper cabling or multimode/singlemode fiber optic cabling. The predominant standards that define structured cabling in North America are the ANSI/TIA-568-C series of standards. The first of these, ANSI/TIA-568-C.0 entitled “Generic Telecommunications Cabling for Customer Premises” introduces the practice of using cabling ‘distributors’ at locations within the network that provide administration, reconfiguration, and connection of equipment and testing. These standards take into account different aspects of one type of premise versus another type. For the factory floor, cabling is governed by ANSI/TIA-1005-A, “Telecommunications Infrastructure Standard for Industrial Premises”. This standard focuses on infrastructure, distance, telecommunications outlet/connector configuration, and topology requirements for cabling deployed in industrial environments.
It is important to refer to or adhere to these standards when considering structured cabling for your specific cabling needs.

The customer premise and industrial premise series of standards refer to component standards that give information about industrial network performance requirements for media, such as twisted pair copper cable and optical fiber. The component standards refer to different levels of cable performance, such as category grades for copper and OM and OS grading for multimode and singlemode fiber when specifying electrical or optical performance of the cabling system.

Structured Cabling Media Considerations

There can be different media choices for backbone (riser), and horizontal cabling. Figure 2 shows the generic cabling topology common to structured cabling. This generic topology is modified to meet the particular needs of the industrial premise and ANSI/TIA-1005-A, “Telecommunication Infrastructure Standard for Industrial Premises,” using a hierarchical star topology.

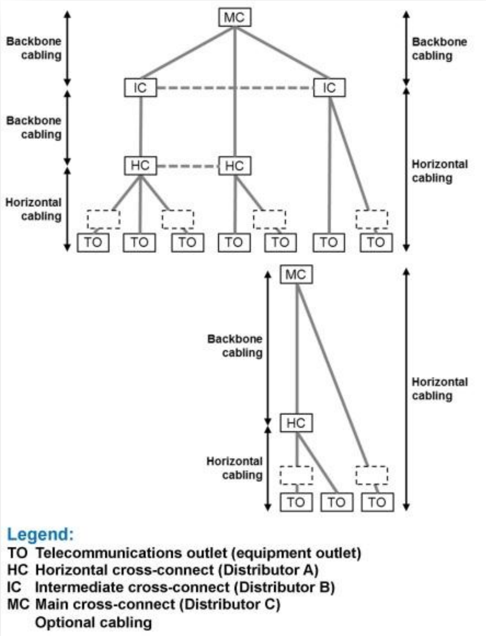

Figure 2. Elements of a Generic Cabling Topology.

Backbone cabling is typically a structured implementation of fiber cabling. Copper structured cabling, because it has distance limitations of 100 meters between active equipment, is normally used for horizontal and work area networks as well as within equipment rooms because of port compatibility with switches and other equipment ports. While copper cabling can be used for backbone cabling, this rarely occurs because the total distance between active equipment is usually more than 100 meters. Optical fiber is most often deployed for backbone cabling because fiber lengths can be significantly longer than those for copper cabling and they support higher bandwidths. In addition, fiber offers higher network resilience through lower convergence times for uplinks and rings as compared to similarly architected copper channels.

Copper and fiber connectivity and media choices must meet Industrial Ethernet/IP electrical and mechanical performance requirements and sometimes must be designed for use in harsh industrial environments.

Table 1 shows some of the key parameters associated with different media choices found in the ANSI/TIA-568-C series.

Table 1. Key Parameters for Cabling System Media

Parameter	Copper Cable	Multimode Fiber	Singlemode Fiber
Reach (max)	100m (330 ft.)	2000m (1.2 miles) 400m	10km (6.2 miles) 10km (6.2 miles)
Noise Mitigation Option	Foil shielding	Noise immune*	Noise immune*
Data Rate	1 Gb/s (Cat 5e, Cat 6) 10Gb/s	1 Gb/s 10Gb/s	1 Gb/s 10Gb/s
Cable Bundles	Large	Small	Small
Power over Ethernet (PoE) Capable	Yes	Yes, with media conversion	Yes, with media conversion

** Optical transceivers can be susceptible to electrical noise*

One last consideration is cabling system longevity. Active equipment such as Ethernet switches often refresh every five to ten years, however the cabling subsystems may have a lifetime of twenty years or more. Once installed into the building infrastructure, there should be no incentive to 'rip and replace'. For this reason, higher performance backbone and horizontal cabling used in permanent links can help to future proof against data rate increases that occur with new equipment refresh.

Permanent Link (Copper Example)

The permanent link is made using a solid conductor cable that does not need to be flexed and has the benefit of lower attenuation than stranded conductor cable, maximizing the cabling length. The permanent link is terminated at both ends by an RJ45 jack. See Figure 3.

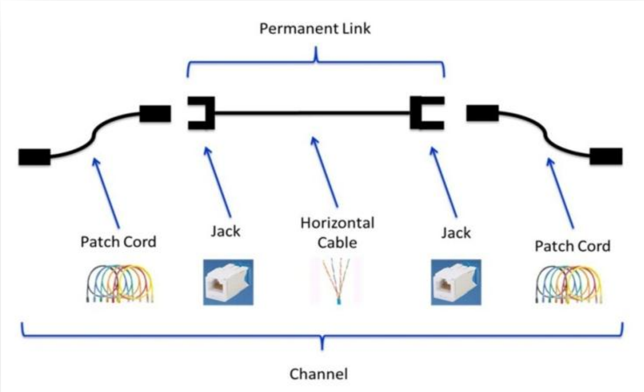

Figure 3. Simplified Example of Copper Structured Cabling.

The permanent link forms the basis for the testable assembly. Any future moves, adds and changes would be made through alternative end point connections in a patching field using patch cords. This link is tested at the completion of the installation by the installer to assure customer verification and warranty specifications are met. Patch cords, required to meet performance specifications per TIA standards, are used at both ends to connect to the equipment. Use of tested patch cords and verified permanent links will assure you have met standards requirements. To achieve optimum data communications between the switch and the work station, wireless routers, machines, cameras and other devices, the entire channel must meet performance requirements specified in the standard. Any weakness in the channel can result in dropped packets, which will degrade communication.

An integrated or pre-configured network zone system exemplifies the use of structured cabling for both fiber and copper with the implementation of fiber backbone permanent links made from the micro data center switch down to the zone switch in the enclosure. A zone system that is populated with switches and network distribution components becomes an active zone for cabling and network distribution from higher levels of the network such as a micro data center.

In Figure 4, optical fiber enters the zone enclosure and is terminated to fiber connectors inserted into adapters in the patch panel. Fiber patch cords are used to connect from the patch panel to the switch uplink ports. For high availability deployments, two uplink ports are used to serve as a main and redundant path.

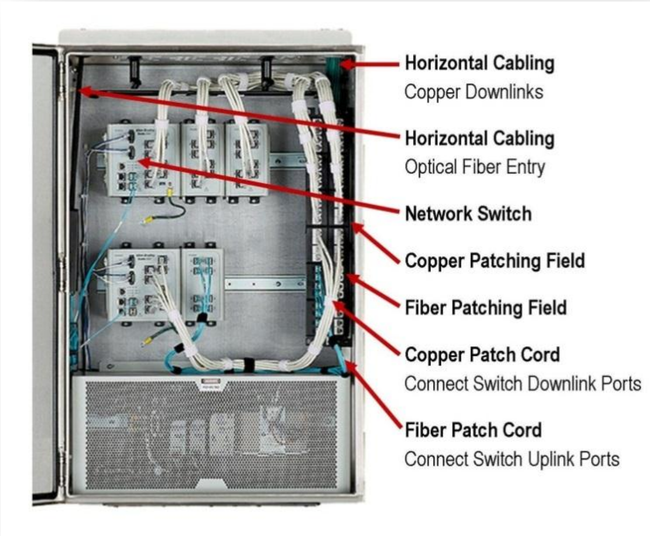

Figure 4. Integrated Network Zone System permanent link implementation.

The permanent links servicing the switch ports are normally routed to manufacturing. Patch cords, (white), connect the switch ports to ports in the patch field on the right side of the enclosure. The horizontal cables are terminated to the rear of the patch panel, leading to machines, control panels and devices. Where a 19" patch panel does not fit in a control panel (or is not right-sized to the number of switch ports), new innovations from Panduit, such as the DIN Rail Mount Adapter and DIN Rail patch panel, bring structured cabling into a control panel or enclosure.

Point to Point Cabling (Fiber Example)

Point to point cabling may be better suited for control panels, on-machine applications, high flex applications and some device-level network topologies. The reasons include:

1. Limited room to install a patching field.
2. Ring or linear network topologies where the application is to be wired in-place and static.
3. Cost to benefit - although structured cabling provides testability and troubleshooting advantages over point to point cabling, the value proposition to justify the added cost of structured does not provide these advantages.

Figure 5 shows a schematic of a fiber point to point cabling system. This can be compared to and contrasted with the structured cabling schematic shown in Figure 3.

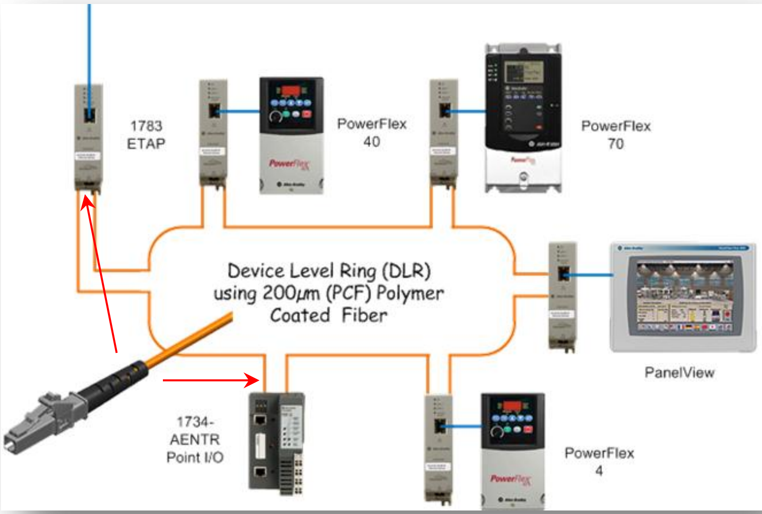

Figure 5. Device Level Schematic of a Fiber Point to Point Cabling System.

Point to point is a direct connect cabling solution from the device port to a connector terminated to the cable. Unlike structured cabling, which is a planned deployment, point to point cabling is applied in the field as needed. The cable is usually pulled between the end points and terminated in the control panel or near the machine. Point to point connectivity can be implemented in two ways:

1. Purchase a complete pre-terminated solution (pre-cut and connected cabling).
2. Build onsite with connector and cable components.

Pre-terminated assemblies are terminated and tested in the factory, thereby assuring compliant performance. Cables can be shielded twisted pair (STP), unshielded twisted pair (UTP) or fiber, depending on the need to mitigate electrical noise. For long reach and/or high electrical noise applications, fiber is recommended. Recent innovations in fiber such as Polymer Clad Fiber (PCF) connectors greatly ease installation and can be installed onto PCF cable by an electrician onsite. Installers select pre-terminated assemblies to the closest sold length needed to connect devices and equipment. Pre-terminated assemblies are available in various lengths, which may result in cabling slack. In this case, excess length of cabling has to be coiled in or near the control panel.

Installations using purchased patch cords can have a larger number of coiled patch cords which can become cumbersome, possibly interfering with other cables and making maintenance more difficult. An alternative method is to assemble network cabling onsite, cutting to exact length and terminating with connectors. Field terminable connectors are recommended. Testing cords can be a challenge for copper systems, depending on the test instrument. Test instruments disregard the plug as it interfaces directly to the instrument. However, basic cable testing is recommended.

Routing needs to be considered when connecting devices between two enclosures with pre-terminated assemblies. If the cable is routed through conduit, the connector may interfere with the pulling operation. Snagless modular plugs in the case of copper (or staggering plugs along cable) may help. Pre-terminated fiber assemblies pulled through conduit must be done with a pulling sock or similar device to protect the integrity of the connectors. However, the most common method of deployment is to pull cabling through the conduit and terminate with field terminable connectors after the pull.

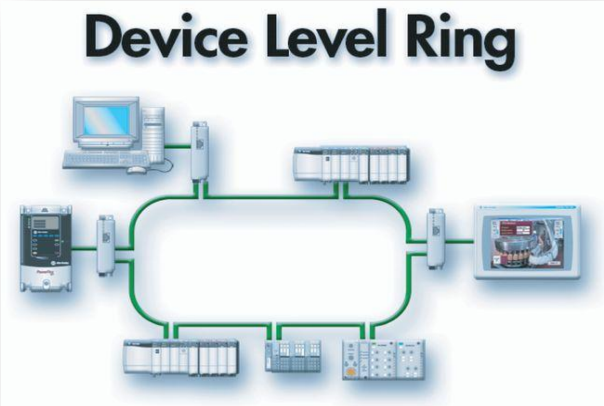

Figure 6. The Use of Point to Point Cabling in a Device Level Ring Topology. *(Rockwell Automation)*

Figure 6, from Rockwell Automation, shows a use case architecture for point to point cabling that is deployed in the field. Here, devices are connected in a ring topology using the Rockwell Automation 1783-ETAP embedded 3 port switch. As these switches are connected into their mounting arrangements, the two ports for the ring topology (the third port is for the networked device) are most conveniently addressed by the use of point to point cabling. When two ETAPs are connected together as consecutive pieces of equipment in the ring (or linear topology), the use of patch panels and connector terminations would not be required, and may present difficulties in access and mounting.

Copper Point to Point Cabling Considerations

In most copper point to point installations, stranded cabling will be used. Stranded cabling is advantageous to accommodate occasional flexing, tight bends or frequent changes in direction. Another consideration is the reduction in distance due to stranded cable attenuation. For installations reaching the maximum distance specifications (100 meters), stranded cabling may not meet performance specifications. Also, if re-termination is required, cable slack is needed. For example, if the RJ45 plug suffers damage or is installed improperly, re-termination is necessary.

Conclusion

When assessing your cabling network topology to determine whether you should use structured cabling or point to point cabling, the primary considerations are your design specs, network longevity, maintainability and installation. These considerations will help you choose the best cabling option for your Ethernet industrial automation application. Table 2 explains the pros and cons of selecting a structured cabling implementation versus point to point implementation.

Table 2. Deployment Examples for Structured and Point to Point Cabling

Primary Considerations	Structured Cabling	Point to Point Cabling
Meet Design Specifications	• High cable density - many cables from panel to panel • Testability at the panel can provide assurance for commissioning new ports and may yield potentially longer warranty terms	• Low cable density - few cables from panel to machine • Ring or linear topology for reach beyond 100 meters where distance between connections is <100 meters • PCF for long reach or noise mitigation
Network Longevity (Future Proof)	• Designed in spare ports (no need to re-pull new cables for 'adds') • Fiber backbones with higher grade fiber such as OM3 or OM4	• Impractical to have spare cable runs laying loose and/or unprotected • Higher performance with fewer connectors
Maintainability (Moves, Adds, Changes)	• Environments with multiple changes occurring • Cable slack is required	• Environments with minimal changes occurring • Slack cabling is undesired and precise cable lengths are required
Installation	• Multiple points of connectivity • Backbone and horizontal cabling is largely untouched	• Quick installation • Use where tight bends or moderate flexing is required • Use in areas where it is impractical or impossible to mount a patch panel or other cable connector interface

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References

[1] *I.H.S. Global/IMS Research. The World Market for Industrial Ethernet & Fieldbus Technologies – 2013 Edition.*