# Industrial Ethernet on the Plant Floor

## A Planning and Installation Guide

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# Introduction

Ethernet emerged more than twenty years ago as a commercial network, providing office connectivity to desktop computers and printers. Office environments are relatively benign with respect to electrical noises. Applying the same network in an industrial environment presents the designer and installer with some challenges in obtaining equal or better performance. Machine control demands reliable data transport to ensure maximum network availability and uptime.
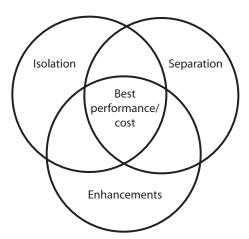


**Figure 1–1** *Cost and Performance Optimization*

A solution may be provided by employing component enhancements, isolation, and separation from the environment. Applying the three correctly will yield the best performance at a minimal cost. These options will be discussed throughout the book. The following chapters will guide you through the basics and advanced designing of industrial Ethernet networks.

## 1.1    Industrial Ethernet Networks

There are three basic media Ethernet types: coaxial, twisted pair, and fiber. The most common type found today is twisted pair. The use of coaxial networks has declined due to their connection costs and installation complexities. Coaxial-based networks supported a maximum of 10 Mb/s and were limited to lengths of 200 meters (10Base2) and 500 meters (10Base5). Today's generic networks support 10 Mb/s, 100 Mb/s, and 1 Gb/s, 10 Gb/s and will soon also support 40 and 100 Gb/s. These new high-speed networks will primarily use copper twisted pair and fiber as the physical layer media. The emerging industrial networks are using copper twisted pair and fiber, and will primarily use 10 Mb/s and 100 Mb/s. There are two variants for copper twisted pairs, shielded (STP, ScTP, FTP etc.) and unshielded (UTP). The following chapters will discuss the merits of shielded and unshielded cabling and when to use each of them.

Today's industrial network focus has extended Ethernet networks into control applications. This new network will not, however, supplant the existing fieldbus networks in the near term.

Currently, there are several industrial Ethernet networks defined by various consortia, including EtherNet/IP™, Modbus-IDA (Interface for Distributed Automation), and PROFINET.

This book will help bridge the gap between the multitude of industrial Ethernet-based networks and the lack of installation guidance for the designer, planner, and installer.

Voice Video and Data applications use cabling that is designed and installed as generic telecommunications infrastructures. The components and networks are designed in accordance with the TIA 568 (A and B) standards and the ISO/IEC 11801 standards.

There are additional industrial Ethernet standards that define performance and provide installation guidance in development. There are

currently two international standards organizations that have written and released standards for industrial Ethernet.

1. ISO/IEC/JTC1/SC25/WG3/IPTG released ISO/IEC 24702

2. IEC/SC65C/JWG10 released IEC 61918

Nationally, the Telecommunications Industry Association TR42.9 is writing TIA 1005, Industrial Telecommunications Infrastructure.

In addition, there are several consortia that have released standards that define performance and installation requirements.

> ODVA (Open DeviceNet Vendors Association), provides EtherNet/IP™ and EtherNet/IP™ CIP (Control and Information Protocol) standards and installation guidance.

> ControlNet International being one of the CIP members, provides EtherNet/IP™ CIP standards and installation guidance.

> PNO, PROFINET organization.

This book will cover the important installation topics and procedures for the networks listed above.

## 1.2 Differences between IT Networks and Industrial Control Networks

IT personnel have been providing network services for computing connectivity in the office for many years. The need for simple, reliable, and inexpensive connectivity has created an interest in moving network services into industrial environments. However, there is little similarity between the front office and the factory floor with respect to the environment. In fact, the noise level in the harsh industrial environment is a factor of ten times greater than that of the office environment. Further, networks deployed for factory automation applications are considered "mission critical," requiring high reliability infrastructures. These challenges have spurred the recent creation of the industrial infrastructure standards for performance and installation in both ANSI/TIA and ISO/IEC. In addition, many industrial controls companies, such as Rockwell Automation, have been providing Ethernet-enabled controls equipment that is compatible

with networks designed to these standards. This new breed of PLCs and IO incorporates Ethernet as a control and information network. Most of these products have Web interfaces to help with configuration and maintenance.

In industrial application, machine control traffic is dependent on unrestricted access to the network. The reliability of the network on the factory floor is mission critical. To illustrate this point, we can say this: "If my computer cannot connect to the network in the office, I may not be able to print or access my email." The cost to the company is minor and there is no product waste. If, however, the control network fails in the factory, many workers are idled, machines cannot run, and production stops. The dollar cost can be in the hundreds of thousands per hour in lost productivity and revenues, not counting scrap. It does not take many network failures before a company begins to feel the financial losses, which could potentially lead to bankruptcy. A designer should keep this in mind when purchasing components and products for industrial applications. Ask yourself this question—would you bet your company on a nine-dollar NIC card from the local computer store?

The noise in the industrial environment is at least a magnitude greater than the office environment. Industrial controls engineers expect an equal or better performance than that of a front office network. For example, IEEE 802.3 requires devices to meet a certain level of performance with 1V of noise, whereas industrial standards typically require the same performance in the presence of 10V of noise. Given this, the network components must be designed to have greater noise immunity and/or be protected from the high EMI within the environment. Later in this book we will discuss a new concept called MICE (Mechanical, Ingress, Climatic/Chemical, and Electromagnetic). Further, we will show how to apply the MICE concept to determine the appropriate network components or protection (isolation, separation) for the environment. Most industrial Ethernet networks use a combination of communication stack optimization and bandwidth to achieve pseudo-deterministic performance. Some customize the hardware to achieve deterministic behavior. The use of custom hardware raises questions regarding open standards, availability, and breadth of selection.

## 1.3    Deciding Which Network to Install

Industrial control applications allow topologies that are not supported by the generic standards. For example, a simple point-to-point connection between a switch and a PLC may be required, and the generic standards require the channel to contain a fixed horizontal cable with a work area cord, patch panel, and outlet. These requirements may be too complex and, in many cases, needless. Therefore, as part of the decision process, one must consider the needs of the application and which standard should be supported to meet the appropriate needs. In general, the generic standards should be followed whenever possible. These standards will provide the best success in meeting the requirements for standard IT applications, such as voice, data, and video.

A network standard or network wiring book is not complete without showing the generic wiring infrastructure. Figures 1–2 and 1–3 describe the cabling infrastructure in TIA terms. Figure 1–2 is a top-down hierarchical drawing, beginning at the Campus Distributor and ending at the Intermediate Distributor. This shows how a system can grow from two buildings (BD), horizontally, to cover many buildings. Additionally, each floor will have at least one Floor Distributor (FD) and possibly many Intermediate Distributors (ID), depending on the square footage of the floor coverage area. The hierarchical configuration shown in Figure 1–2 provides redundancy at each level through the dotted line connections.

Another way to look at this infrastructure is to flatten out the view. This drawing also shows how the Automation Island connects to the generic telecommunications infrastructure. In Figure 1–2, the system ends at the Telecommunications Outlet (TO). In Figure 1–3, the generic cabling system ends at the TO or AO (Automation Outlet).

If the TO is replaced with an AO, the network may no longer be compliant to the generic standards. This can be said for any part of the network where deviations exist. This is permissible as long as performance is met and the designer is aware of the ramifications.

In most applications, more than one connection is needed. In this case, the network will either connect to the ID without a TO or AO, or the ID will be moved inside the Automation Island. Connectivity from one Automation Island to another will be done directly or through the ID, as detailed in Figure 1–4, or directly between two automation islands.
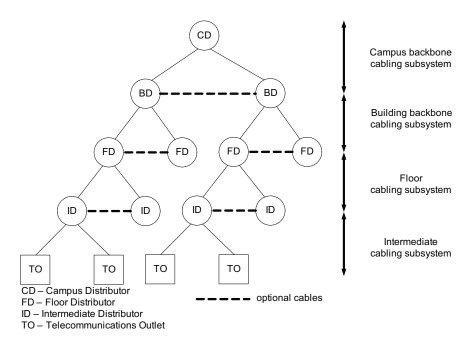
CD – Campus Distributor
FD – Floor Distributor
ID – Intermediate Distributor
TO – Telecommunications Outlet

– – – – – optional cables

**Figure 1–2**   *Generic Telecommunications Infrastructure with Optional Redundancy*
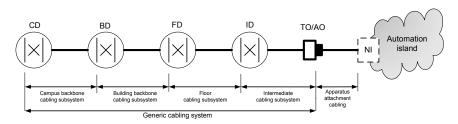


**Figure 1–3**   *Industrial Connectivity to the Generic Telecommunications Infrastructure*

In some cases, the ID may move into the Automation Island or there may be a need to support many different applications in the Automation Island, such as voice, data, video, and control (VDVC). If the Machine Distributor is in a harsh environment (MICE 2/3), its construction may be different. Figure 1–5 introduces a Machine Distributor (MD) to distinguish between a distributor made for normal MICE 1 environments and one for an industrial environment.
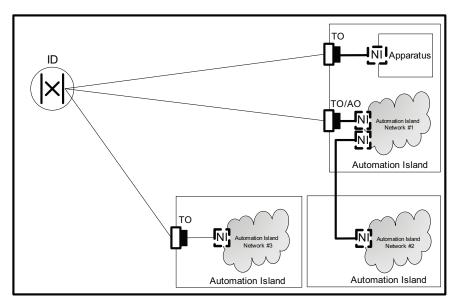
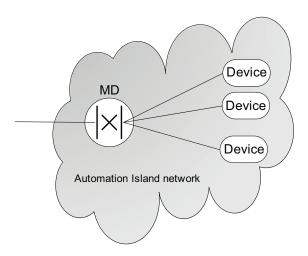**Figure 1–4** *Expansion of Generic Telecommunications Infrastructure*



**Figure 1–5** *Connectivity Inside an Automation Island*

The following examples will show Ethernet-based control and information network connectivity within the automation islands. Figure 1–6 is an example of the implementation of a generic cabling system inside the Automation Island. There are restrictions placed on the cabling
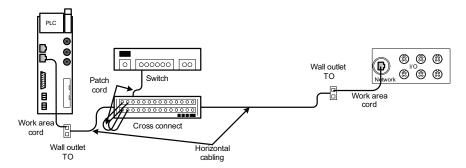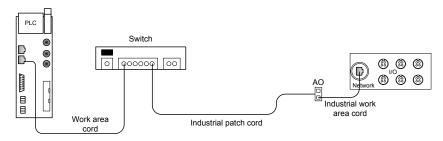
**Figure 1–6**    *Example of an Ethernet Control System Using Generic Cabling*

system so that the cabling will support all of the supported applications (VDV) and now control. In a compliant generic system, devices must connect through a work area cord from a TO. Between the cross connect and the TO/AO must be horizontal cabling to form the fixed part of the cabling system. The TO/AO must be placed within 5 meters of the work area cord. The distance between the cross connect and the TO/AO is limited to a maximum of 90 meters. In a generic cabling system, the horizontal cabling must be constructed of solid copper conductors. In an industrial cabling system, the horizontal cabling may be stranded cabling. This is largely due to the expected movement and flexing of the cabling components.

If a cabling infrastructure or machine cabling is only intended to support control applications, generic cabling methods may be too restrictive. The international standards for industrial Ethernet are being written to provide definitions and guidance to the machine area or Automation Island. If the network provides connectivity to one of the fieldbus networks within the Automation Island, the TO should be replaced by an AO. In this case, the AO that should be installed is defined by the specific fieldbus to be used. Chapter 5 will give guidance on which of the AOs are allowed by each fieldbus standard. You should immediately notice how simple the point-to-point examples are as shown in Figures 1–7 and 1–8. There are several trade-offs in these topologies which may not make a difference in industrial networks.

- Future network reconfigurations may be more difficult.

- The network may not support all applications, such as 1 Gb/s, POE, or video, especially if 2-pair cabling is used.

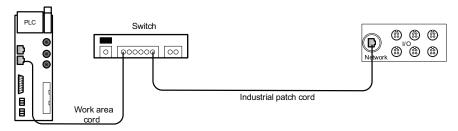**Figure 1–7** *Example of a Control System Using Reduced Cabling*



**Figure 1–8** *Example of a Control System Using Minimum Cabling*

- The benefits may far outweigh the loss in flexibility. Machine wiring is usually more permanent than office connections (less moves, additions, and changes).

- Generally, the more connections that are in the channel, the greater the chance of a failure.

In short, flexibility comes at a cost and may not be needed for your application.

For the sake of differentiation, each cord is given a name. Each of the cords have attributes that differentiate it from other industrial cords and cords used in commercial networks. These are only examples of typical attributes. The actual cables used may have different requirements.

**Work Area Cord.** This cord is usually installed in an enclosure and only requires protection to IP 20. In most cases, a standard "off-the-shelf" cord will work.