A Guide to Industrial Communication Protocols

Introduction

Industrial automation – the control of machinery and processes by autonomous systems using technologies like robotics and computer software – is one of the major forces driving Industry 4.0. This automation is being driven by high-speed communications between devices and software. For the wide variety of industrial automation devices to communicate, a standard communication protocol must be employed. Essentially, industrial protocols are communications protocols that ensure connectivity between machines, devices, and systems as part of an industrial network.

Initially, industrial communications were based on serial connections. Many of the serial-based protocols – generally called Fieldbus networks – are still used today, such as Modbus and Profibus. However, in the past decade or so industrial automation has shifted away from serial towards Ethernet communications, resulting in protocols like EtherNet/IP and Profinet. Though to a much lesser extent, wireless communications like WLAN and Bluetooth are also being deployed in industrial automation applications. Broadly, the major industrial automation communication protocols can be divided into industrial Ethernet, Fieldbus, and wireless.

Industrial Ethernet

Among the three major industrial network categories, industrial Ethernet is the largest and the fastest growing. According to the annual HMS Industrial network market shares report, industrial Ethernet applications account for 68% of the global market of newly installed nodes in factory automation, representing a 10% growth from 2022. There are two main reasons for this: Ethernet connections have higher speeds than serial fieldbus and wireless connections, and Ethernet cables can be effectively extended to much longer distances than either serial connections or wireless connections.

Within the many industrial Ethernet protocols, there are a few that are more prominent.

PROFINET

According to the same HMS report, PROFINET - Process Field Network – and the next entry – EtherNet/IP – are tied for the most used industrial network protocols, with each holding an 18% market share. PROFINET is developed and maintained by PROFIBUS & PROFINET International (PI), a non-profit trade organization. In general, PROFINET is employed more often across Europe than in the U.S.

PROFINET is an open Ethernet-based protocol that grew out of and is a direct extension of PI's experience with the serial-based PROFIBUS protocol. Because of the close relationship between the two protocols, PROFIBUS devices can integrate seamlessly into a PROFINET system.

The PROFINET protocol defines the communication between components, like alarms, diagnostics, functional safety, and additional information. Standard Ethernet cables connect PROFINET components within a network, allowing other Ethernet protocols to coexist within the same infrastructure. Alongside PROFINET, you can employ other Ethernet-based protocols like SNMP, MQTT, or HTTP to complement the network.

EtherNet/IP

As noted above, EtherNet/IP shares the position of most used industrial network protocol with PROFINET, with each accounting for 18% of the market share. EtherNet/IP is open-source and is managed and developed by the Open DeviceNet Vendors Association (ODVA), a tax-exempt business league that includes a wide variety of hardware and software manufacturers. Whereas PROFINET is used mostly in Europe, EtherNet/IP is used primarily in the U.S.

EtherNet/IP combines the Common Industrial Protocol (CIP) with standard Ethernet technology. CIP is a media-independent, object-oriented communication protocol designed for industrial automation applications and based on the producer-consumer communication model. The CIP protocol incorporates a comprehensive stack of messages and services that support the integration of industrial automation applications with enterprise Ethernet networks and the Internet, facilitation of data exchange between network components, monitoring and control, synchronization, and network management.

One of the major benefits that EtherNet/IP offers is the ability to connect legacy devices. EtherNet/IP's structure allows the ability to connect devices from any OEM to the network, thereby enabling access to the machine data platform. This eliminates the need for proprietary protocols that require expensive investment into a single vendor's product.

EtherCAT

Ethernet for Control Automation Technology (EtherCAT) is an open-source Ethernet protocol. EtherCAT was initially released by Beckhoff Automation in 2003. Then, in 2004, Beckhoff donated the rights to the EtherCAT Technology Group.

EtherCAT has a few unique features and characteristics. The protocol utilizes a distributed clock mechanism. Each device in the EtherCAT network synchronizes its internal clock to a reference clock. This timing feature allows precise and synchronized communications across all devices on the network. EtherCAT utilizes a master-slave structure and transmits data throughout the network in a novel way. The master is the only device that is allowed to transmit data, but each slave device can read, modify, and add data as the original transmission is passed through the network. This eliminates the need for data to traverse the entire network loop, reducing communication latency and enabling real-time control and response.

Fieldbus

According to the HMS report, Fieldbus networks account for 24% of the global market of newly installed nodes in factory automation, representing a 5% decrease from 2022. While Fieldbus networks have been declining in deployments since 2018 – the first year that Ethernet deployments became a majority – there are still many use cases where a Fieldbus protocol may be more applicable than an Ethernet protocol:

- **Legacy Systems**: if using existing automation systems or devices that use Fieldbus protocols, it can be more practical and cost-effective to continue using Fieldbus to maintain compatibility with those systems. Replacing all the devices or retrofitting them to use Ethernet-based protocols can be a complex and expensive undertaking.

- **Limited Bandwidth**: If a system has low bandwidth requirements, such as simple I/O control or monitoring applications, Fieldbus protocols will be sufficient. Ethernet-based protocols may be unnecessary if the network bandwidth is underutilized.

- **Simple Networks**: Fieldbus protocols are well-suited for simple network configurations, such as point-to-point or multidrop setups, where a limited number of devices need to communicate over a single communication line. In these cases, Fieldbus protocols are simpler to implement and maintain compared to Ethernet-based protocols.

- **Deterministic Behavior**: Fieldbus protocols offer inherently deterministic behavior. The timing and sequence of data exchange can be highly predictable and consistent. This is particularly important for applications that require precise control and synchronization, such as motion control or distributed control systems. While Ethernet networks are fast, they are not deterministic. The speed of Ethernet can overcome some determinism concerns, but not all of them.

Modbus

Modbus, initially developed in 1979, is the oldest protocol in this list. Traditionally, Modbus was/is implemented using RS-232, RS-422, or RS-485 serial connections. There are several different Modbus protocols, but far and away the most common is Modbus Remote Terminal Unit (RTU).

Modbus RTU makes use of a compact, binary representation of the data for protocol communication. The RTU format follows the commands/data with a cyclic redundancy check checksum as an error check mechanism to ensure the reliability of data. A Modbus RTU message must be transmitted continuously without inter-character hesitations. Modbus messages are framed (separated) by idle (silent) periods.

Like every protocol on this list, Modbus has some major benefits and some significant drawbacks. To start with the positives, Modbus is very easy to implement. It is the perfect solution for very simple applications. Further, as it is open source, and has been around since 1979, there are innumerable pages of documentation, use cases, and best practices available. Finally, implementing Modbus is incredibly cost-effective.

Modbus also has some drawbacks. First, RS-232, RS-422, or RS-485 serial connections have significantly slower transfer rates than Ethernet connections. Modbus supports a limited set of data types, primarily focused on numerical values and discrete inputs/outputs. Handling more complex data structures, such as strings or arrays, may require additional encoding or custom implementation. Finally, as Modbus is a basic protocol, it lacks advanced features like built-in diagnostics, redundancy mechanisms, or extensive error handling. Modbus is still an excellent choice for simple or small-scale automation tasks.

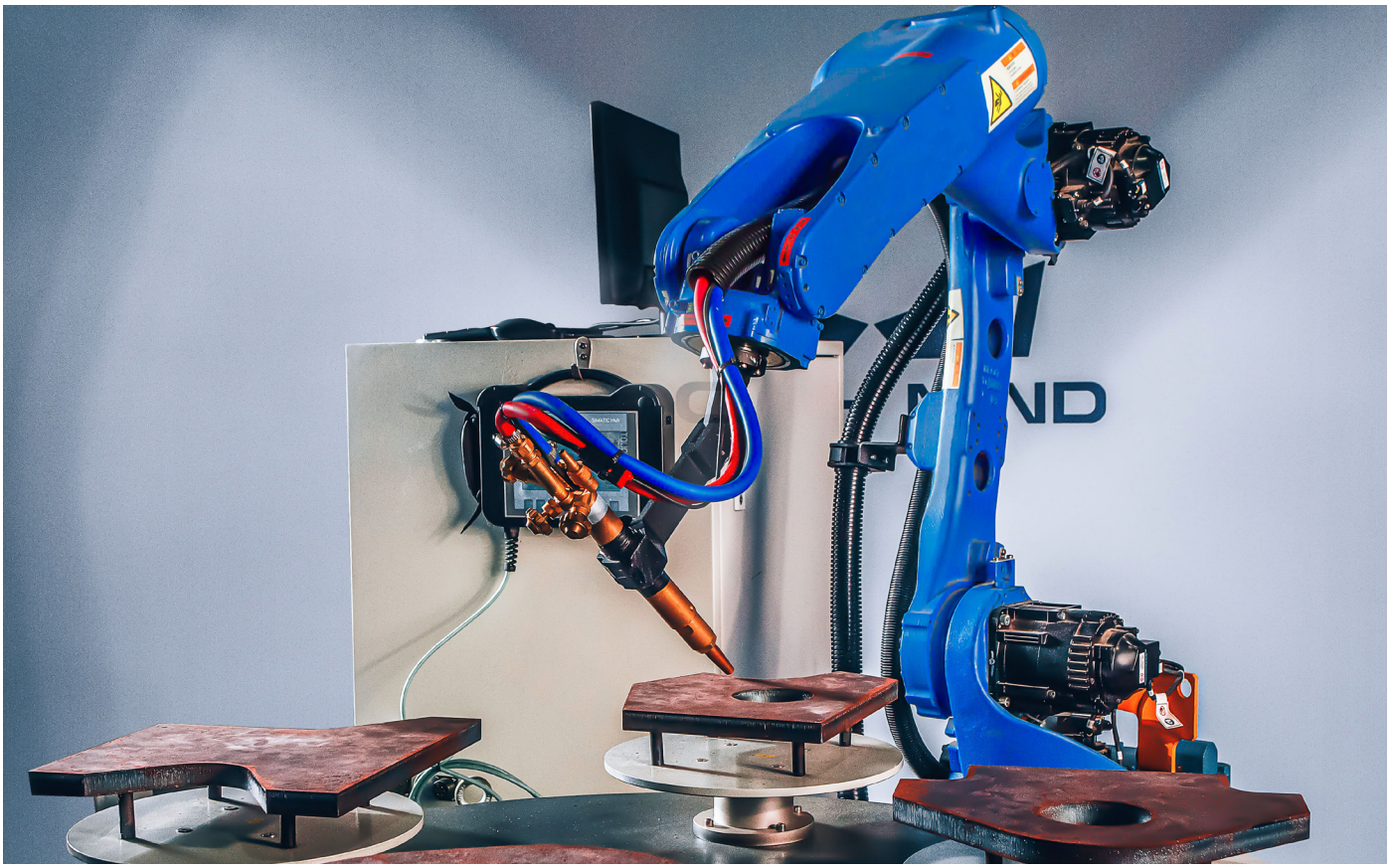
PROFIBUS

PROFIBUS - **Pro**cess **Fi**eld **Bus** – is the most widely deployed Fieldbus protocol. PROFIBUS – like its cousin PROFINET – is developed and maintained by PROFIBUS & PROFINET International (PI), a non-profit trade organization. In general, PROFIBUS is employed more often across Europe than in the U.S.

The general principle of PROFIBUS is collecting multiple inputs and outputs from the field into a local IO device, and then transferring the data through just one cable to the master. This approach saves costs by the omission of additional hardware and cabling. Also, it saves engineering time as it streamlines network installation, maintenance, and troubleshooting.

Again, there are benefits and drawbacks to using PROFIBUS as a protocol. In terms of benefits, PROFIBUS can support much higher transfer speeds than Modbus. PROFIBUS deployments are known for robustness and reliability and can withstand harsh industrial environments. PROFIBUS is a very robust protocol that was designed to automate entire plants. It works extremely well in multivendor applications, with modems, and has detailed diagnostics.

However, deploying a PROFIBUS network is very complex and requires specialized knowledge and experience. While the protocol is faster than Modbus and other serial networks, it is still significantly slower than Ethernet-based networks.



Conclusion

Ultimately, the selection of an industrial communication protocol depends on the requirements and constraints of the application. For simple networks with deterministic control requirements or networks with a small, fixed number of devices, a Fieldbus protocol will often be the best choice. For large networks or networks that are projected to grow, or networks that require high-speed data transfers, an Ethernet-based protocol is likely more suitable. When deciding on a network, whether using a serial-based Fieldbus network, an Ethernet-based network, or even a wireless network, it is crucial that the devices and hardware that comprise the network are compatible. Many off-the-shelf devices have built in support for one or another protocol, but some may require additional modules or adapters for proper integration. It is also important to observe industry standards and guidelines that are relevant to your application as specific applications may have required communication protocols.

About the Author

Drew Thompson is a marketing specialist for Sealevel Systems. A writer/editor by training, he spends his days creating and delivering content relevant to our technical community and business partners.