Technical Paper

Safe Digitization Down To The Field Level

Ethernet-APL as an enabler for enhanced plant efficiency

April 2022

Ethernet-APL brings the benefits of digital communication to harsh environments of the process industry at the field level. The universal use of Ethernet-APL makes it possible to consolidate an infrastructure for safety-related and non-safety-related communication. Even so, complete separation is preserved and maximum availability and safety are ensured. The digitization through the use of Ethernet-APL ensures full information transparency from a sensor to the cloud. This information is available for evaluation across all automation levels throughout the entire plant lifecycle. This paper describes the features, benefits, and challenges of the new technology and draws comparisons to preceding ones.

The time-to-market aspect is crucial to the success of a plant operator. For new plants, the focus is on the planning, engineering, and construction phases. For existing plants, however, the primary concern is efficient change management, as plants today must be able to respond flexibly to market demands. Moreover, maintenance and repair account for a significant proportion of the costs of operating a plant, and can frequently exceed the acquisition costs. This is why it is important to consider all the components and their interaction in the entire lifecycle of operating a process plants for cost effectiveness.

Striving for more flexibility is as old as automation itself. A major step in this direction was the decentralization through remote I/O. Here, data of various I/O types can be converged or distributed on site. The connection to higher-order levels for processing is established via digital networks. This approach has improved over the years, resulting in remote I/O concepts e.g. for operating functions, safe automation, flexibly configurable I/O and for accessing the Ex-Zone. Unfortunately, these concepts are often oversized and they merely exchange process values at the field level.

HART takes a different approach. The communication protocol exploits the existing analog signals and additionally communicates modulated data to the devices directly connected to the field level. This approach, however, still has drawbacks such as the reduced accuracy of the analog values, a still considerable wiring effort and missing properties for functional safety.

A good combination of the two concepts, with a fully digital communication with a direct network connection of the sensors and actuators to the field level, would therefore be the ideal solution. Ethernet-APL is designed precisely for this purpose and enables end-to-end digital communication down to the field level of process automation.

The tasks of Ethernet-APL

Modern communication systems are structured in several layers (**Picture 1**: ISO/OSI 7-layer model). Each layer provides different capabilities and can be replaced by other technologies operating on the same layer.
The lowest layer is the so-called "physical layer". APL stands for "**A**dvanced **P**hysical **L**ayer" and, like "Fast Ethernet", "WLAN" or "fiber optics", it describes the physical transmission of data. Each of these connections is designed for a specific area of application. Ethernet-APL combines some very important features for process automation such as:

- 2-wire connection with reverse polarity protection (SPE, Single Pair Ethernet)
- 10 Mbit/s per connection, making the fieldbus solutions more than 300 times faster than existing ones
- Full duplex switched Ethernet, enabling existing topologies like “star” or “ring”
- Distances up to 1000 meters with full preservation of data quality
- Point-to-point connections, enabling simple network design and network maintenance
- Data and power transmission on the same line
- Communication in explosion-protected area (up to Ex-Zone 0 Div.1)
- Robust design for industrial environments
- Standardized and thus future-proof

The ISO/OSI layer interchangeability allows for easy conversion from Fast Ethernet to Ethernet-APL. Pepperl + Fuchs, for example, proves the point with an Ethernet-APL switch that is used as a media converter from Fast Ethernet to Ethernet-APL.
With respect to the physical layer, it makes no difference which higher-order layers are involved in the communication and which data is exchanged. Well-known higher-order layers are IP and TCP/UDP. These higher-order protocols are also interchangeable if they are on the same layer. It is only in the application layer that data is given meaning. A protocol of a higher layer widely used in automation is Modbus, which can use TCP or UDP as well as Fast Ethernet or Ethernet-APL. Modbus is a simple example. For universal automation solutions, however, more modern and universal protocols with a wider range of applications are more interesting.

An example of a widely used, well proven and open industrial protocol is PROFINET. In addition to many other benefits, it also provides PROFIsafe, an open protocol for functional safety that establishes a "black channel" between a host and a device, ensuring detection of potential errors in intermediate communication layers. Consequently, thanks to the interchangeability of the underlying layers, PROFINET and PROFIsafe can be transmitted via both Fast Ethernet and Ethernet-APL.

Technologically, Ethernet-APL is stepping up to replace existing 4…20 mA solutions as well as remote I/O. This is a major promise and requires manufacturers and users to rethink their applications. As with all technology or paradigm shifts, digitization should not be an end in itself. It should create true added value in real plants.

Test setup at BASF

BASF in Ludwigshafen has set up a fully functional network with Ethernet-APL components to gain practical experience and insights. The test setup also includes a prototype with Ethernet-APL, PROFINET and PROFIsafe. This is the first fully functional SIL 3 communication via Ethernet-APL worldwide. The concrete connection must be viewed on two levels:

The physical connection is implemented via Fast Ethernet from the HIMA safety-related controller to the Ethernet-APL switch from Pepperl + Fuchs. This is done in the usual way using an Ethernet cable with RJ45 connectors. From there, it continues with Ethernet-APL. The connection is carried out with a 2-wire cable, which is terminated on both sides with screw terminals. The sensor from Endress + Hauser can then be supplied with power and data.

The logical connection of how the data is exchanged and which significance it has, occurs via PROFINET and PROFIsafe. In this case, the HIMA safety-related controller exchanges data in digital quality directly with the Endress + Hauser sensor via PROFINET and PROFIsafe. This ensures that the data is transmitted from the sensor to the processing unit correctly, unaltered, and with maximum accuracy.

Comparison to existing technologies

The following sections describe the individual benefits of combining Ethernet-APL with PROFINET and PROFIsafe as compared to previous technologies (4…20 mA, HART, remote I/O, fieldbuses):

<u>4…20 mA wiring</u>

The 4…20 mA interface is currently dominant in process automation, primarily for the transmission of safety-relevant data. With regard to the connection technology, Ethernet-APL has the advantage over 4…20 mA technology in that a connection can be established very easily over almost any distance into the field using a single cable. Where increased availability is required, a ring can be used. As such, the wiring effort with Ethernet-APL is significantly lower than with 4…20 mA. Furthermore, there is no need for a marshaling level and, for systems in Ex-Zones, an Ethernet-APL switch replaces Ex isolators, thus saving additional space and cost within the control cabinet.

<u>4…20 mA accuracy</u>

One downside of a 4…20 mA interface is that signals from the sensor to the safety-related controller must be repeatedly converted between analog and digital, which means that the transmitted analog value is prone to interference. This inaccuracy cannot be compensated for by a high-resolution analog-to-digital conversion within the controller. For this reason, safety margins must be planned.

However, modern transmitters process the internally available data in digital form anyway. With digital communication, the data can be made available unaltered and with higher accuracy. Safety margins can thus be reduced and the plant can be operated closer to its limit. Depending on the process, this can result, for example, in increased output, lower power consumption, or better quality of the goods to be produced.

4…20 mA information content

The information content of 4…20 mA is rather low and the value must always be interpreted in the processing unit. Furthermore, the valid range for process values is between 4 mA and 20 mA. As a result, a value above 20 mA is not a valid process value and indicates an error state. In turn, this means that either a process value or an error will be displayed.

With digital transmission, multiple values such as process value and health status of the field device can be transmitted. If the field device detects the need for maintenance, this can be communicated in the digital data record. The plant can continue to operate until preventive maintenance is performed, thus ensuring increased plant availability.

4…20 mA with HART

HART modulates digital data onto the analog signal, allowing for additional information such as the health status of a field device to be transmitted in addition to the process value. This transmission via HART is very slow, does not provide much data, and affects the accuracy of the process value. Neither can the additional data be used for safety-related applications.

Conversely, with a digital connection with Ethernet-APL and PROFINET, large amounts of data can be made available very quickly. With PROFIsafe, the information can be used directly for safety engineering. For example, in the case of differential pressure measurements, even additional process values (both pressures) can be evaluated from a safety viewpoint. Even the units of the measured values can be transmitted, making it unnecessary to interpret the data in the safety-related controller because this information is directly provided from the field.

Central configuration and start-up are possible with both the HART and the Ethernet-APL/PROFINET solution. Thanks to its faster transmission capability, Ethernet-APL offers much more extensive options.

Remote I/O with or without flexible I/O

Compared to the 4…20 mA solution, remote I/O with or without flexible I/O have the advantage of less wiring and thus usually are more flexible with easier planning. In the end, however, they only move the I/O into the field and are still 4…20 mA interfaces. Therefore, the lower information content and the inaccuracy of the process values (almost) correspond to the direct 4…20 mA solution. Depending on the design, the hardware overhead and space requirements are also significantly lower with Ethernet-APL than with remote I/O.

<u>Fieldbus systems</u>

Fieldbus systems such as PROFIBUS represent a first approach to establishing digital communication at the field level. For the most part, serial connections are used here. Fieldbus has the drawback of being very slow (factor 300) and quite error-prone compared to Ethernet-APL (nothing is more annoying than a forgotten terminating resistor).

Ethernet-APL: Future capability and challenges

Modern approaches to process automation benefit from the use of Ethernet-APL to extend high-performance networks down to the field level. Concepts such as NOA (Namur Open Architecture), MTP (Modular Type Packages), modern AMS (Asset Management System) or even visionary approaches such as 'control in the field' can only unfold their potential if performance and information content from the field increase significantly.

Of course, new technologies bring new challenges. For minimum complexity and maximum cost efficiency, all field devices in a plant must be consistently integrated via Ethernet-APL. Consequently, the entire sensor and actuator portfolio should be available at the field level for operation and safety functions.

Connecting a single digital input or output does not yet make sense from an economic point of view. In this respect, remote I/O do have their merits. They can be integrated in the same network, even if other protocols are used on higher layers. The principle should be: networking where possible, wiring where necessary!

The security aspect should also be considered from the outset. Ethernet-APL is merely a "physical layer", so the security concepts developed both in the standard (IEC 62443) and by user organizations (e.g., PI) can be applied.

Added value with Ethernet-APL

Ethernet-APL qualifies for both new (greenfield) and existing plants (brownfield). The benefits described earlier in this paper relate to technical characteristics. Depending on the application, however, these benefits can be extended even further.

Our experience at HIMA shows that requirements may vary from one plant to the next. Different field devices are suitable for different applications. The openness of the interfaces combined with the resulting compatibility and interoperability make it possible to use the best field devices in their respective class (best-of-breed). The definition of "best" varies from plant to plant. For example, “best” for one plant may be high accuracy, while for another, high speed, and for yet another plant, low costs.
The openness of Ethernet-APL combined with PROFINET/PROFIsafe also improves the spare parts situation, as alternative devices or successor products can be used more smoothly. The data already in digital form can be perfectly forwarded to higher layers via OPC UA.

HIMA Approach: Independent Open Integration

The flexible HIMA Safety Platform offers a complete portfolio of solutions that meet the highest functional safety and availability requirements. It enables both centralized and highly efficient decentralized solutions. In decentralized solutions, safety-related communication between the safety controllers and to the remote I/O occurs via HIMA's proprietary SafeEthernet protocol.

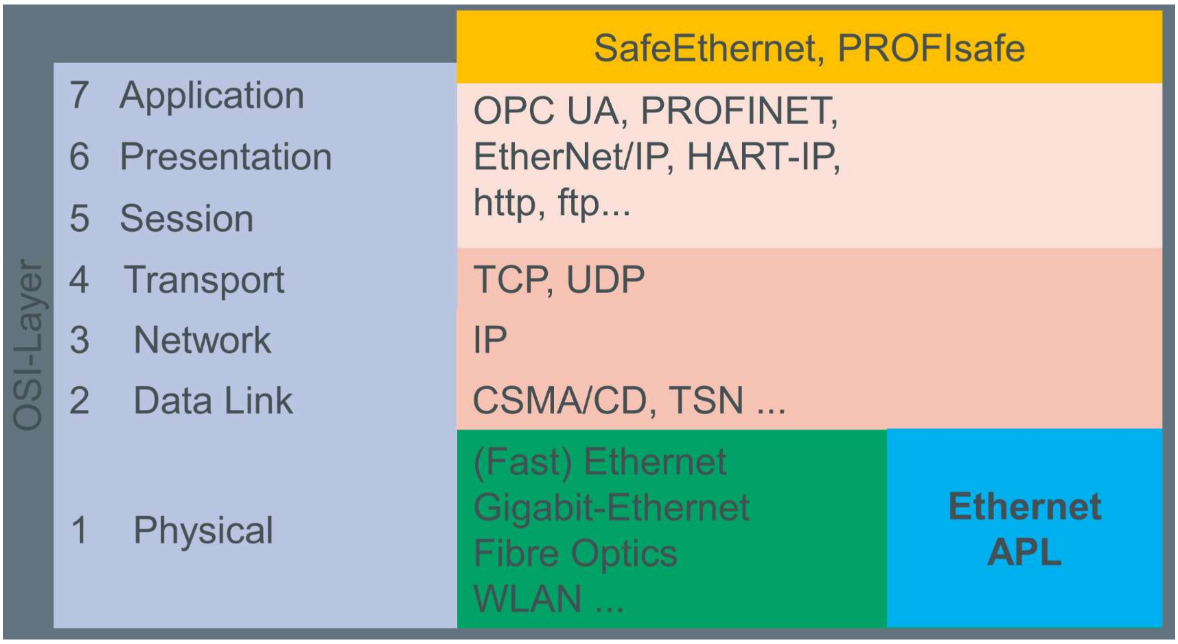
The safety-related systems support all common communication options, including OPC UA and PROFINET. This means that the safety platform can be flexibly combined with the leading DCS systems. Ethernet-APL is now the first to enable the efficient, digital connection of safe field devices. HIMA calls this concept 'Independent Open Integration' - enabling plant operators to implement their individualized solutions. Ethernet-APL now offers even more options for communications down to the field level.

Conclusion

Ethernet-APL provides an excellent digital highway down to the field level to implement customized solutions with best-of-breed products for end-to-end safety.

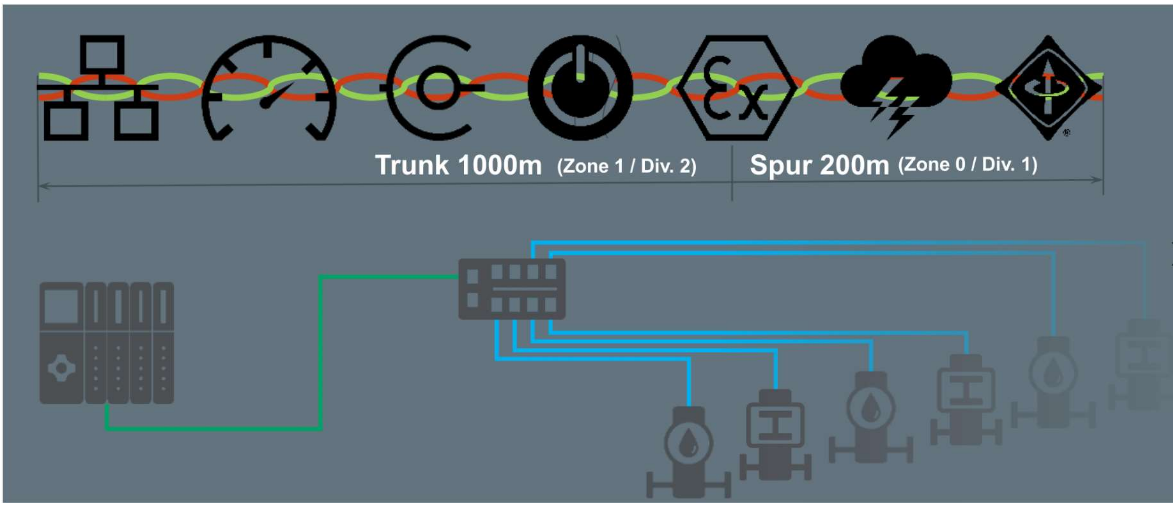

Photo: HIMA Paul Hildebrandt GmbH

Author: Stefan Ditting, Product Manager at HIMA



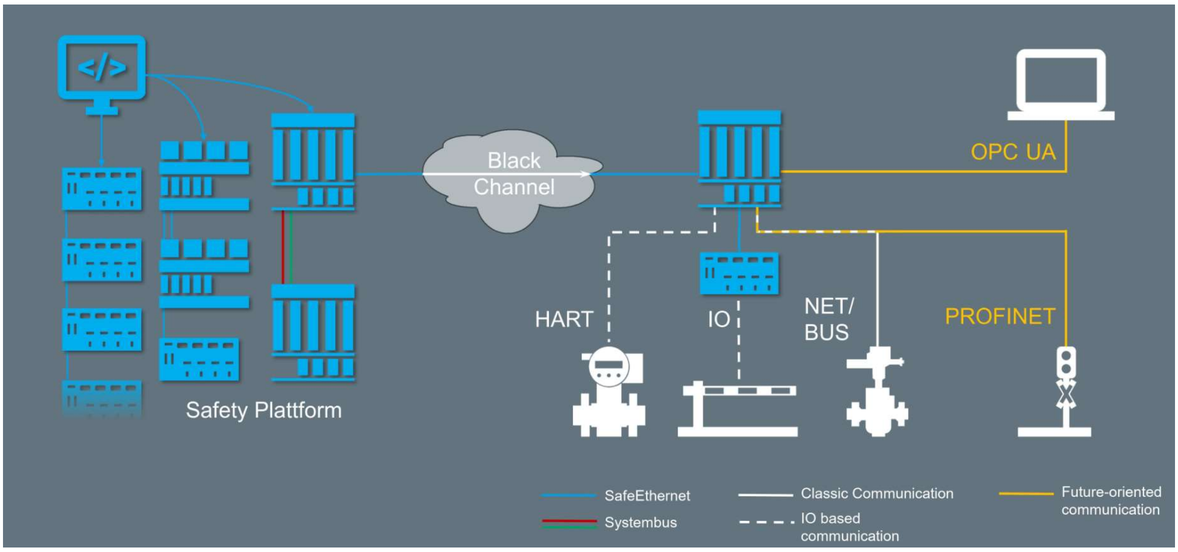
Picture: HIMA Paul Hildebrandt GmbH

Picture 1:
ISO/OSI 7-layer model: Modern communication systems are structured in several layers. Each layer provides different capabilities and can be replaced by other technologies operating on the same layer.



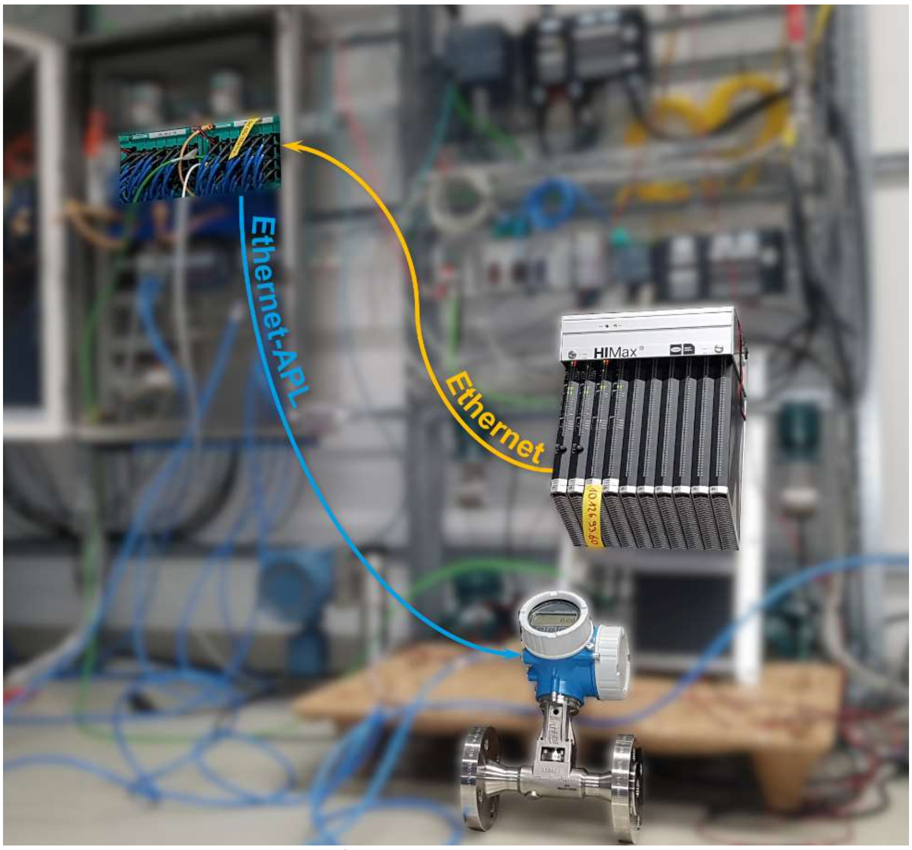
Picture: HIMA Paul Hildebrandt GmbH

Picture 2:
The combination of technical features and easy handling qualifies Ethernet-APL for universal use of communication solutions in the field level.



Picture: HIMA Paul Hildebrandt GmbH

Picture 3:
HIMA's Independent Open Integration concept enables integration into every automation environment.



Picture: HIMA Paul Hildebrandt GmbH

Picture 4:
Test setup at BASF: The world's first SIL 3 communication via Ethernet-APL.