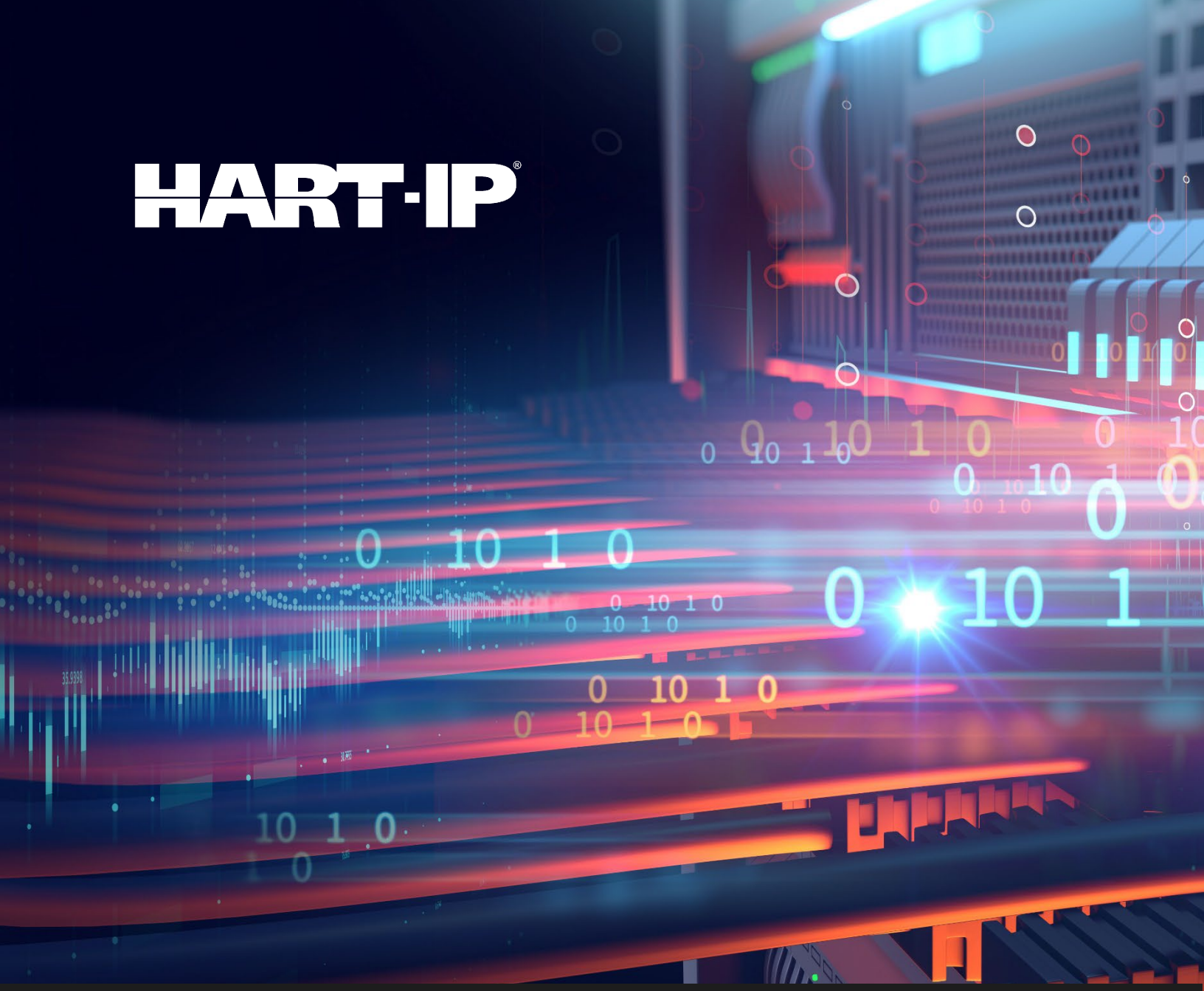

HART-IP: Technical Description

FieldComm Group™
Connecting the World of Process Automation

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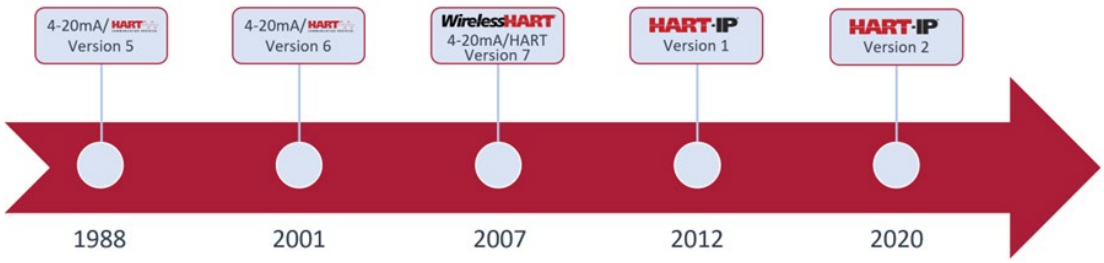
EXECUTIVE SUMMARY

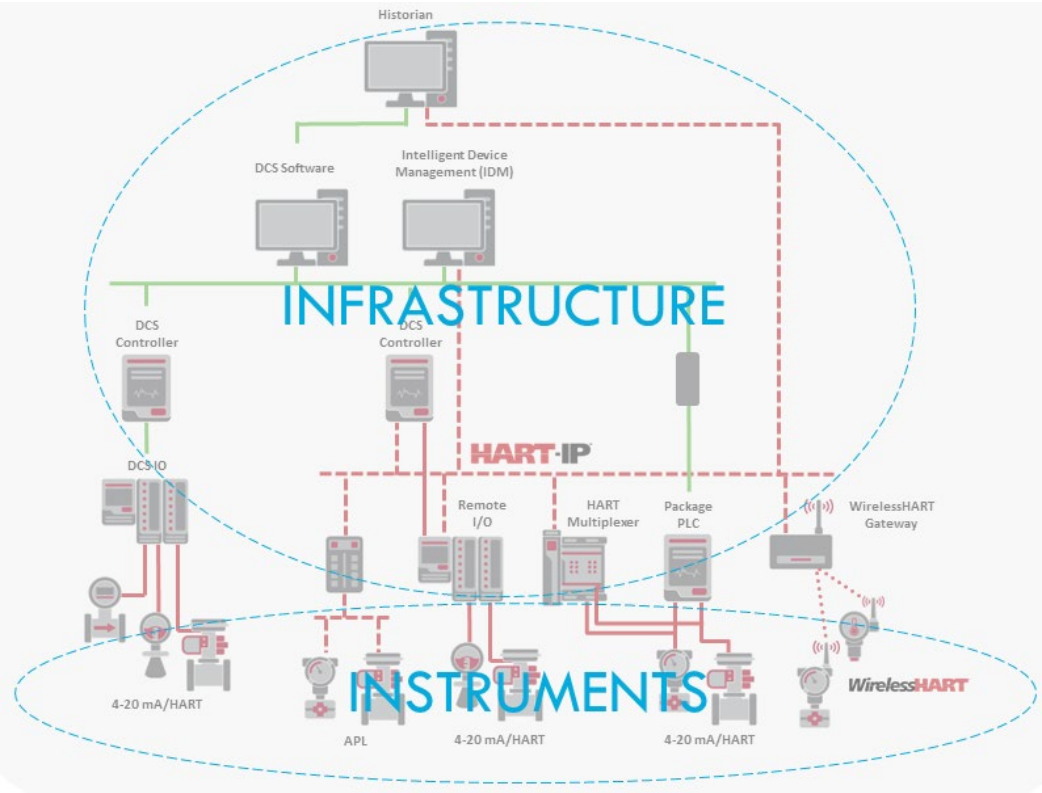
One of the reasons why HART is well-liked by plant staff working with instrumentation is that it is not necessary to understand the underlying technology to use it. Some instrument technicians, who have been using 4-20 mA/HART and WirelessHART instruments for decades, have never even heard about HART commands. This ease of use is a result of several important attributes of the technology. These attributes now carry over to HART-IP technology.

1 HART-IP TECHNOLOGY

HART-IP is an application protocol that works on top of UDP/TCP/IP over regular IEEE802.3 Ethernet and Ethernet-APL. This includes physical media such as copper cable, fiber-optic (FO), Power over Ethernet (PoE), and wireless links using Wi-Fi and other media supporting UDP/TCP/IP like mobile/cellular (3G/4G/LTE/5G), microwave or satellite, all available in industrial grade also for use outdoor and in hazardous areas. HART-IP is fully routable since standard IP is used. HART-IP meets diverse requirements like various topologies, sizes, distance, and explosion protection, etc. thanks to the modular concept of IP-based hardware. That is, networking gear need not be specially “HART-IP compatible”; regular industrial-grade network infrastructure components are used.

Industrial Ethernet is taking the place of RS485 for the I/O infrastructure in plants and Ethernet-APL is taking the place of analog 4-20 mA for the instrumentation in new plants and expansions. Yet, in existing plants, 4-20 mA/HART and WirelessHART will remain for a long time. HART-IP is an application protocol for instrumentation, infrastructure, and associated device management as well as analytics software. HART-IP has been in operation for more than 10 years and is based on the proven and familiar HART protocol, which has been serving the industry for more than 30 years.



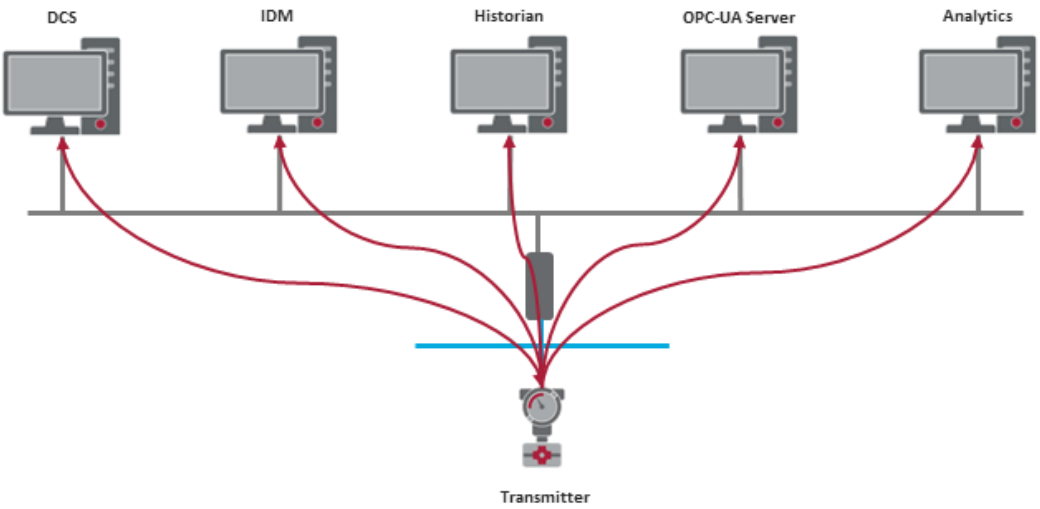


HART-IP products provide a uniform experience with existing 4-20 mA/HART and WirelessHART products – only at much higher speeds. Echo curves that would take minutes to plot with 4-20mA now generate in seconds. HART-IP is compatible with existing instrumentation and ready for the future, thus protecting investments.

HART-IP is found in both hardware and software. Chances are your plant already uses HART-IP and you don't even know it. While HART for 4-20 mA devices are only used for configuration, calibration, and diagnostics, and asset management, Ethernet-APL devices also use HART-IP for real-time transmitter process variable (PV) and controller setpoint output to valves for control. These variables also include status with validity.

1.1 HART Protocol

4-20 mA/HART is a request-response protocol limited to 2 controllers. RS485, as used in HART multiplexers, only supports a single controller. Over TCP/IP and Ethernet, the acyclic request-response relationship has been translated into client-server communication. HART-IP is a client-server protocol that supports multiple simultaneous clients. Field instruments like transmitters and valves as well as infrastructure devices like multiplexers and gateways providing resources are *servers*. Software and system devices like controllers that use these resources are *clients*. A minimum of 5 clients are supported by servers, often more. That is, multiple HART-IP clients like the control system, IDM software, historian, OPC-UA server, and analytics can communicate HART-IP with the device at the same time to get the data they need.

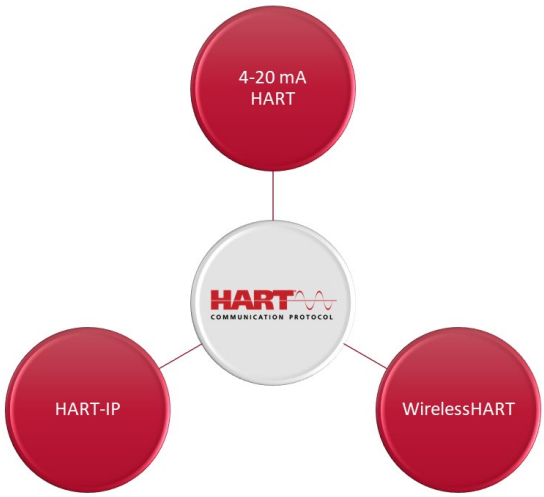


The HART *burst mode* communication has been translated into a publisher-subscriber (pub-sub) relationship carried on top of UDP/IP and is used for cyclic real-time transmission of process variables from transmitters to valves, for monitoring, control, and in the future also for functional safety applications.

HART-IP runs at the speed of Ethernet which can be 10/100/1000 Mbit/s, fast enough for process monitoring, control, Sequence of Events (SoE) recording, turbomachinery protection, and Safety Instrumented Functions (SIF). The HART protocol now includes SafeHART extensions for functional safety. Safety and non-safety devices will be able to coexist on the same network. There will be devices that can be used in safety and non-safety applications.

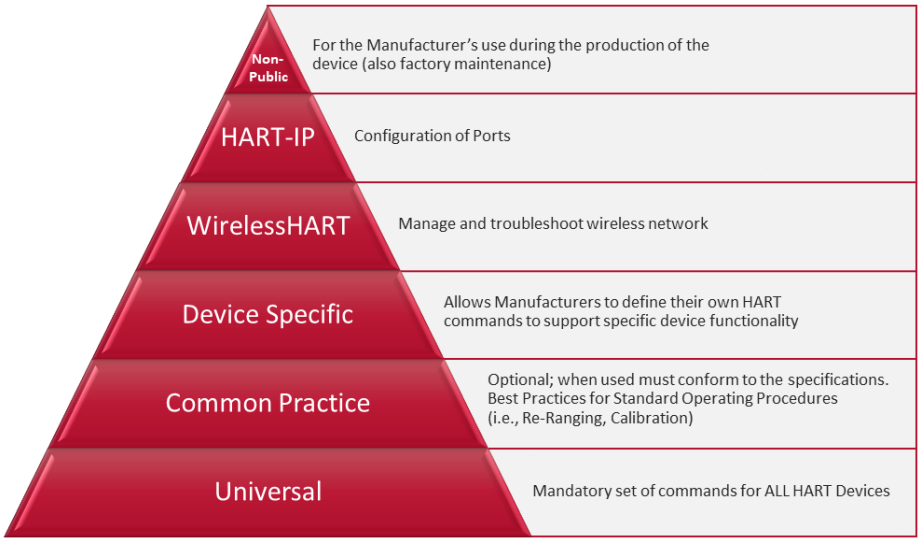
1.1.1 The HART Protocol Family

HART-IP is part of the same HART family of technologies as the familiar 4-20 mA/HART and WirelessHART. HART-IP uses the same application protocol. This application protocol was designed specifically to support all aspects of field instrumentation, not just measurement and control, but also the configuration, diagnostics, calibration and application data. The HART application protocol links these three technologies together.



1.1.2 Commands

To access information, HART-IP uses the same universal commands as 4-20 mA/HART and WirelessHART, and most of the same common practice commands. Some new common practice commands were added specifically for HART-IP. Similarly, HART-IP permits manufacturers to add device-specific commands for special features. Universal commands are mandatory and implemented by all HART field instruments. Common practice commands are optional but implemented the same way in all devices that support them. Commands that read information from a device, group related information together, reading in a single transaction thus reducing traffic.



HART multiplexers and WirelessHART gateways based on HART-IP simply pass through HART commands received over HART-IP from IDM software and analytics to the underlying field instrument and return the response. No mapping to other protocols is needed. The application protocol remains intact thanks to HART-IP. Therefore, IDM software can still use the device EDD/FDI files to automatically access all the data in the field instrument without the need for manual data mapping.

1.1.3 Interoperability

HART-IP interoperability is enabled by universal and common practice commands and EDD/FDI files. Field instruments, control systems, multiplexers, gateways, and software of different versions and models from different manufacturers can exchange data without custom programming or manual data mapping. All device information including detailed diagnostics and configuration can be accessed and displayed graphically by loading an EDD/FDI file for the device on the system. Thanks to universal and common practice commands, the configuration of published and subscribed variables does not require an EDD/FDI file and can be done automatically by the control system based on the control strategy. This reduces the system engineering burden and improves day-to-day ease of use. Alternatively, DTM programs can be used in FDT-based IDM software.

1.1.4 Interchangeability

Similarly, HART-IP interchangeability is also enabled by well-defined universal and common practice HART commands for the most important “core” instrument functions including:

- Monitoring process variables and diagnostic status
- Control the setpoint to valves
- Configuring tag, unit, range, damping, display language
- Track change counter and date of last change
- Factory reset, zero sensor, and simulate

Universal and common practice commands do not change over time, they work the same way in old and new versions of devices, all models, from all manufacturers. This ensures backward and forward compatibility. A replacement device will need to be considered for its matching common practice commands, mechanical configuration, and mounting orientation. With much of HART technology being standardized, this task is made easy.

The control system establishes communication with the replacement instrument even of a different version, model, and make. Similarly, the control system can automatically commission a HART-IP field instrument as soon as it is connected to the network. That is, an instrument technician can replace a field instrument using only a screwdriver, without touching the control system software thus making field instrument replacement easier and eliminating the need for a system engineer or system integrator to participate in the field instrument replacement.

HART *device families* (device profiles) define the interchangeability of additional instrument data. The control system verifies if a device family is supported by the instrument and can assist with instrument replacement.

- Configure temperature sensor type and connection, cold junction compensation
- Configure valve action and auto-calibrate the control valve

1.1.5 Redundancy

HART-IP works across both ring topology networks like Media Redundancy Protocol (MRP) and dual networks with redundant Ethernet switches like Parallel Redundancy Protocol (PRP). Both 1 or 2 Ethernet ports per device are supported.

Controllers: Redundant controller pairs of primary and secondary controllers can support HART-IP devices.

WirelessHART Gateway: Both primary and secondary controllers can read measurement data as well as read and write WirelessHART instrument data through the WirelessHART gateway. For redundant WirelessHART gateways, the primary gateway connects to the primary controller and the secondary gateways connect to the secondary controller.

Ethernet-APL Field Switch: Both primary and secondary controllers can capture measurement values published from HART-IP APL sensors, publish setpoint output to the HART-IP APL positioners, and read and write data in the HART-IP APL instruments through the APL field switch.

Remote-I/O: Both primary and secondary controllers can read and write HART instrument data which pass through the HART-capable remote-I/O subsystem. For redundant remote-I/O subsystems the primary remote-I/O 'head' connects to the primary controller and the secondary remote-I/O 'head' connects to the secondary controller. Alternatively, for redundant remote-I/O subsystems, both the primary and secondary remote-I/O 'heads' connect to both the primary and the secondary controller. A PLC protocol runs in parallel for the I/O signals to and from the PLC.

Both ring topology and dual network enable HART-IP communication to be redirected through a different path with little or no delay.

1.1.6 Timestamp

HART-IP devices can publish timestamped *event notifications* on device configuration change events, device status alarms, or device diagnostics alarms.

1.1.7 Configuration Change Management

All HART devices including HART-IP devices support a configuration change counter mechanism allowing the control system or IDM software to know when any other tool has changed the configuration of a device such that systems can automatically synchronize their database to the latest device configuration thus avoiding inconsistencies. This also enables a complete audit trail.

1.1.8 Test and Registration

The FieldComm Group independently tests and registers HART-IP conformance in field instruments and infrastructure devices. All registered HART devices are listed on the FieldComm Group website www.fieldcommgroup.org.

1.2 IP

HART-IP devices benefit from the capabilities of the Internet Protocol (IP).

1.2.1 Compatibility

HART-IP uses standard Ethernet infrastructure which has a long tradition of retaining backward compatibility as new generations of technology with higher bandwidth or new capabilities are introduced, automatically negotiating speed. Thus, it is easy to retrofit old hardware with a new and better component.

1.2.2 Cybersecurity

HART-IP version 2 mandates the use of standard Transport Layer Security (TLS) and standard Datagram Transport Layer Security (DTLS) providing encryption, authentication, and integrity check, plus standard syslog for events, and internal audit log for server activity such as in field instruments, multiplexers, and gateways. The security mechanisms are the same in all HART-IP products from all manufacturers, so they all interoperate.

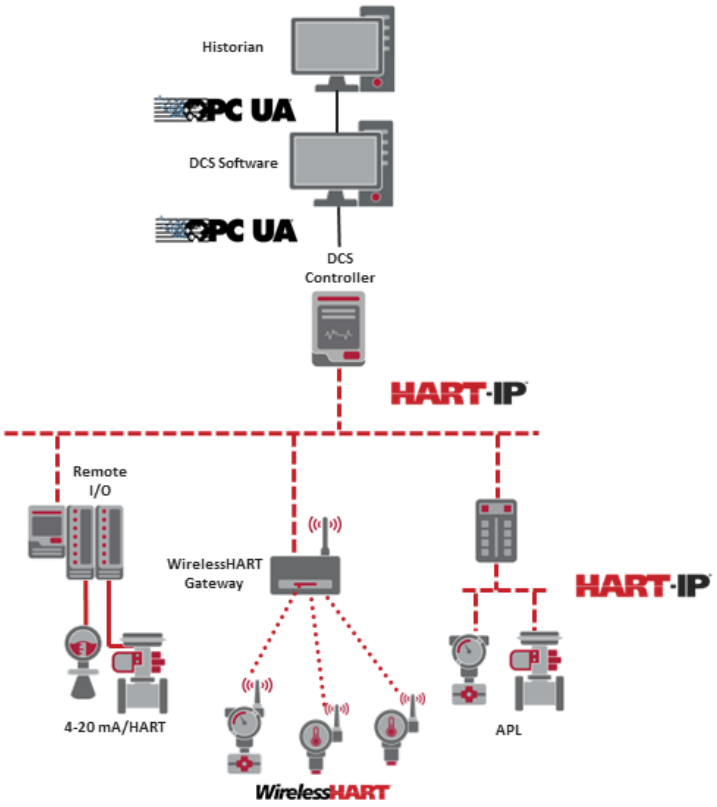
The network over which HART-IP is transported can make use of the wide range of security solutions available for IP over and above TLS/DTLS; such as firewalls, intrusion detection systems, VPN tunneling, and many others. A system can thus be designed to provide multiple layers of security for defense in depth. HART-IP has a default port (5094) making it

easier to manage filtering and blocking. Once communication between a HART-IP client and a device has been established, security is enforced.

1.2.3 HART-IP I/O System

A HART-IP input/output system such as a WirelessHART gateway or HART multiplexer has multiple WirelessHART or 4-20 mA/HART devices connected respectively below it. The I/O system caches data from the underlying devices to provide a fast response over HART-IP. The I/O system automatically detects all the underlying WirelessHART or 4-20 mA/HART devices enabling engineering software and IDM software to automatically display the network topology.

HART-IP is used in level 0 instrumentation and level 1 infrastructure while level 2 and level 3 software may use OPC-UA for open communication, with some overlap options. Note that wired, wireless, and Ethernet-APL instrumentation all use the same HART application protocol for simplicity.



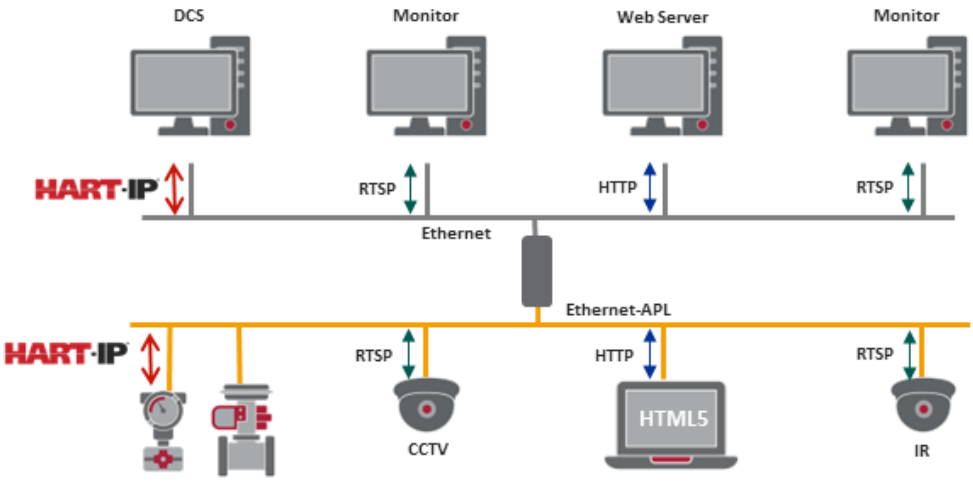
1.2.4 Coexistence

HART-IP coexists in parallel with other communication protocols on the same Ethernet wires, such as between IO-subsystems and controllers and from controller to controller. That is, unlike traditional “bus” systems which only support a single protocol, IP on Ethernet is a multi-protocol environment that has made the Internet so successful with specialized protocols coexisting in parallel.

1.2.5 The IP Multi-Protocol Philosophy

HART-IP as a specialized instrumentation protocol follows the Internet Protocol (IP) multi-protocol design philosophy where each function has its specialized protocol. HART-IP is used for communication with field instruments while controller to controller and controller to server computers may use OPC-UA, and IP cameras

use RTSP, etc. This clear distinction between functions by protocol/port makes it easy to shape network communication traffic for a mix of instruments, controllers, and IP cameras, etc. filtering and blocking for security and Quality of Service (QoS) prioritization. Note that the various systems sharing the same network infrastructure use different access credentials such that a person working on the video system cannot access the control system and vice versa.



Control systems, SIS, and IDM software support HART-IP but may at the same time also support other protocols. Field instruments supporting HART-IP may also support other protocols, such as a web browser. This way devices can be selected independently of the main system.

1.2.6 Ethernet-APL

Ethernet-APL is two-wire including power and communication. Ethernet-APL supports both hazardous areas and non-hazardous areas. Intrinsic safety is easy thanks to the 2-WISE concept, which has international recognition through the IEC60079-47 standard. Ethernet-APL grounding and shielding also meet these requirements. Ethernet-APL devices support multiple modes of explosion protection, including intrinsic safety, non-incendive, explosion-proof/flameproof, etc. Ethernet-APL runs at 10 Mbit/s thus capable of supporting many devices and many fast control loops.

Ethernet-APL has high EMI/RFI immunity for Electromagnetic Compatibility (EMC) for use in industrial environments. Single and multi-point grounding is permitted. Ethernet-APL uses a single pair of shielded twisted pair cables. Ethernet-APL instruments are typically connected using simple and rugged screw or clamp terminals for long life. No special tools or field assembly of connectors is required. An Ethernet, and Ethernet-APL, switch port is its own network thus HART-IP devices can be added without disturbing other devices on that switch. HART-IP devices have the HART-IP logo engraved or otherwise labeled. Ethernet-APL devices are additionally marked with the Ethernet-APL logo.

ethernet-apl™
advanced physical layer

HART-IP™

The long-term infrastructure lifecycle cost of a single shared Ethernet-APL network is expected to be lower than multiple infrastructures for 4-20 mA, on-off, RS485, VBS video, and other signal types found in a plant.

2 WHY HART-IP?

As I&C engineers are delivering new control systems, modernizing existing control systems, and executing the digital transformation use cases identified for Industrie4.0, HART-IP makes this work easy at every stage of the system lifecycle for all these systems:

Let's examine each one of these stages.

2.1 SMART PLANT FEED

The decision to build a 'smart plant', a plant 'born digital' is usually made at the Front-End Engineering and Design (FEED) phase of the project. The decision to go with Ethernet, Ethernet-APL, and HART-IP is also decided at this stage.

2.1.1 Single Industrial Ethernet Infrastructure Instead of Multiple RS485

In the past, plants had to use multiple dedicated networks based on RS485 wiring such as Modbus/RTU, PROFIBUS-DP, and many others to support multiple types of devices including HART multiplexers (HART MUX). Multiple network infrastructures are costly to install and maintain. Moreover, RS485 to Ethernet converters are required to interface with computers.

New plants and even retrofits can now use Ethernet as a single shared network infrastructure in place of multiple RS485 networks, and HART-IP as the application protocol used for field instrumentation and infrastructure including analyzers. Other IP protocols can exist in parallel on the same shared infrastructure for other equipment like motor starters and drives, weighbridges, power meters, etc.

2.1.2 Better Multiplexers

The first generation of HART multiplexers based on RS485 installed in plants are aging and have begun to fail and must be replaced. Moreover, the low speed of RS485 is a bottleneck that slows down field instrument configuration upload and download, as well as diagnostics monitoring.

Ethernet-based HART multiplexers with HART-IP are taking the place of RS485-based HART multiplexers to "future-proof" the system and make it easier to manage and make Integrated Device management (IDM) software respond faster. HART-IP helps put 4-20 mA/HART to good use.

2.1.3 FDI Instead of Data Mapping

Other automation protocols were primarily designed to carry inputs and outputs between I/O-systems and PLCs, between motor drive and PLC, or from PLC to PLC, generally mapping a single or a few pieces of information per

field instrument sufficient for process control but insufficient to make good use of smart field devices. Mapping detailed instrument data is time consuming and error prone, and very challenging to maintain over time.

The HART family of protocols, including HART-IP, was designed for the management of the field instruments themselves including the display of measurement status, device status, detail diagnostics, auxiliary measurements, and calibration using IDM software. This is made possible by the field instrument's Device Description (DD), newer Electronic Device Description Language (EDDL), or the latest Field Device Integration (FDI) device package to automatically display all the field instrument information without manual data mapping. This makes system integration a lot easier. By not mapping instrument data to other protocols, HART-IP preserves the ability to use DD/EDD/FDI files. Other protocols cannot achieve a comparable result.

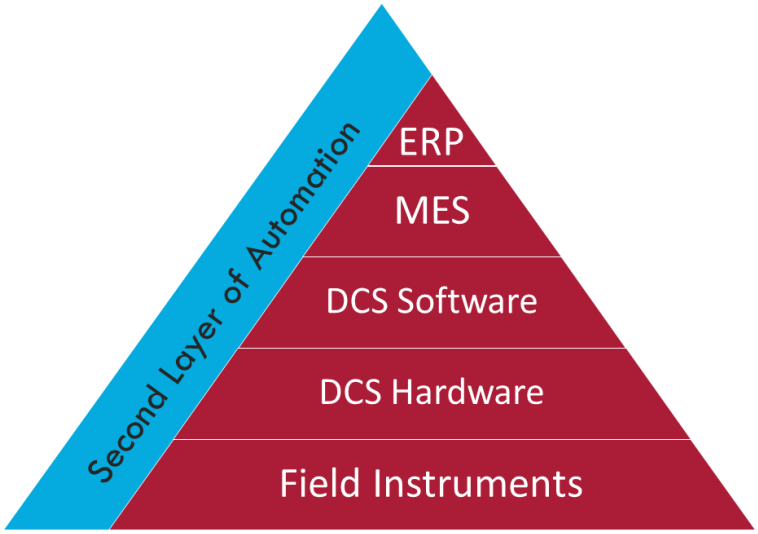
2.1.4 Manage Wireless Transmitters

As part of Digital Transformation (DX), plants deploy hundreds or thousands of WirelessHART sensors to fully instrument equipment to feed data into predictive analytics. All these sensors must be managed.

Thanks to HART-IP, I&C engineers can manage WirelessHART sensors using the same IDM software they use for 4-20 mA/HART instruments, gaining access to the required instrument identification, configuration/setup, and calibration data as well as auxiliary measurements simplifying their day-to-day work.

2.1.5 Second Layer of Automation

Many of these additional WirelessHART sensors feed data directly into analytics software for vibration, corrosion, relief valves, steam traps, etc. as part of a second layer of automation for Monitoring & Optimization (M+O) on the side of the traditional pyramid of automation of Core Process Control (CPC). This is lots of data and some of it is in data formats that do not lend itself well to mapping to other protocols.



HART-IP direct from the WirelessHART gateways into the predictive analytics software eliminates the need for data mapping, again saving project time.

2.1.6 Pass-Through Instead of HART Multiplexer

Many older Safety Instrumented Systems (SIS) do not support HART communication pass-through for the 4-20 mA/HART instruments. Therefore, HART multiplexers were used to access the non-PV data such as diagnostics. This takes up additional marshalling cabinet space and requires additional cabling and integration effort.

Thanks to HART-IP, a third-party SIS not natively integrated with the DCS as an Integrated Control and Safety System (ICSS), but with pass-through of underlying 4-20 mA/HART instrument data, can be integrated with IDM software much easier than using a separate HART multiplexer thus saving project time.

The same applies to Remote Terminal Units (RTU), flow computers, PLC, and remote-I/O supporting HART-IP.

As of version 7.9 of the HART communications protocol, HART 4-20 mA, WirelessHART, and HART-IP devices are now capable of deployment in SIS when they conform to SafeHART requirements defined in the new specification[1].

2.1.7 Ethernet-APL Instead of Analog 4-20 mA

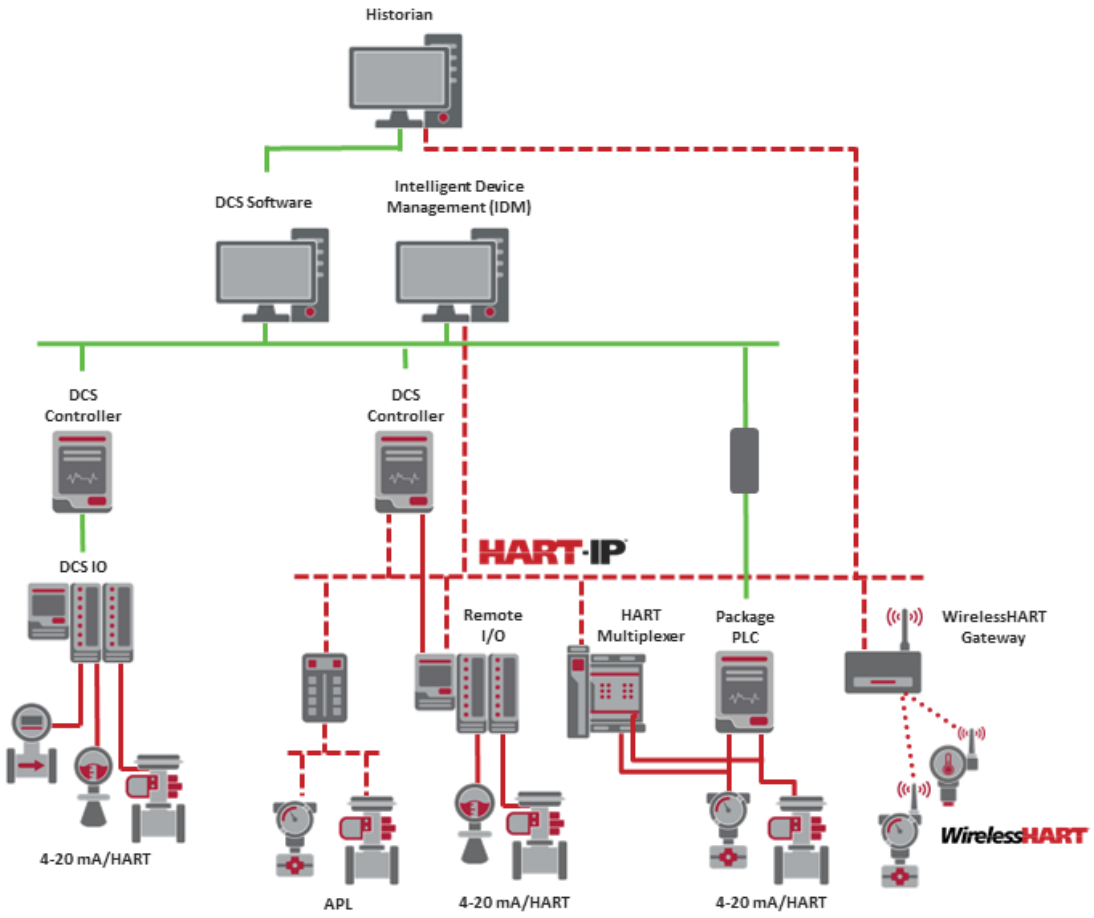
Analog 4-20 mA imposes many limitations on devices such as not measuring over full sensor limits, no validity indication, conversion errors, single signal per wire pair leaving device functionality unused, limited power for 2-wire devices limits capabilities and performance, functionality of devices cannot be linked together, undetected on-scale signal errors, expansion is expensive, and range must be set in the transmitter just to name a few.

Ethernet has been used in control system control networks for the past 25 years. Now Ethernet is making its way into the field. IEEE802.3cg 10Base-T1L Ethernet-APL (Advanced Physical Layer) is fully digital and therefore avoids the limitations of analog 4-20 mA. Ethernet-APL uses 2-wires also providing device power and can be deployed in hazardous areas with intrinsic safety – a feature previously unattainable with prior versions of Ethernet technology. HART-IP is an application protocol available for Ethernet-APL field instruments.

2.2 Easy System Design

HART-IP makes design easy for control system architects as regular Ethernet and Ethernet-APL take the place of RS485, 4-20 mA, and on-off signals. Registered HART-IP product candidates can be reviewed online at https://www.fieldcommgroup.org/registered-products

[1] HART Communication Protocol specifications are available online at https://www.fieldcommgroup.org/hart-specifications



2.2.1 Intelligent Device Management (IDM)

IDM software is used for field instrument configuration/setup, diagnostics, calibration management, and viewing auxiliary measurements. IDM software supports HART-IP for pass-through from third-party systems such as HART multiplexers, WirelessHART gateways, and SIS. Thanks to EDD/FDI, IDM software can access all the unique features of a field instrument. An EDD/FDI file for a 4-20 mA/HART instrument or WirelessHART sensor can still be used even though the data has been transferred through a gateway over HART-IP because HART-IP preserves the application protocol. This makes the design of IDM systems easy since additional interface and protocol converters or driver software are not required. Another technology to integrate field instruments into IDM software is Field Device Tool / Device Type Manager (FDT/DTM). Any FDT-based IDM software becomes HART-IP and WirelessHART enabled with FDI by installing an iDTM.

WirelessHART Gateways

Many plants now have plant-wide WirelessHART coverage with WirelessHART gateways in every plant unit integrated using an Ethernet backhaul network. A site may have hundreds and even thousands of WirelessHART sensors for automating manual data collection as part of the digitalization of how the plant is run and maintained, particularly the maintenance, reliability, integrity, energy efficiency, as well as occupational safety and health work processes. Advanced sensors are key to the digitalization of activities. HART-IP enables WirelessHART gateways and IDM software from different vendors to work together with minimal effort.

Remote-I/O

Some plants use remote-I/O. Modern remote-I/O subsystems use an Ethernet backhaul network. HART-IP enables remote-I/O and IDM software from different vendors to work together without the need for custom driver software. This makes the design of remote-I/O subsystems easier. By eliminating dedicated RS485 networks and serial-to-Ethernet converters system integration is greatly simplified.

HART Multiplexers

Many plants rely on HART multiplexers because HART is not supported in their control system. A HART multiplexer is connected in parallel with conventional 4-20 mA I/O cards tapping into the HART communication as a proxy. Modern HART multiplexers use an Ethernet backhaul network. HART-IP enables HART multiplexers and IDM software from different vendors to work together without the need for custom driver software. This makes the design of multiplexer systems easier. By eliminating dedicated RS485 networks and serial-to-Ethernet converters, package unit integration is greatly simplified.

2.2.2 Third-Party System Pass-Through

Because HART-IP preserves the HART protocol commands, this makes it easy to design systems where 4-20 mA/HART and WirelessHART devices below third-party systems such as PLC, SIS, or RTU of a different brand from the DCS are integrated into the IDM software.

2.2.3 Control Systems

Plants are now designed with control systems using Ethernet-APL instead of 4-20 mA and on-off signals. Control systems support interfaces such as Ethernet-APL switches and the HART-IP protocol making integration of Ethernet-APL instrumentation easy.

Existing Control Systems

Older control systems can often have firmware and software updated to a new version supporting HART-IP. In the interim, these older control systems that don't support HART-IP can use Modbus/TCP which may also be supported in some Ethernet-APL field instruments, but possibly at additional cost. That is, for these older systems, integrate transmitter process variable and valve setpoint to the control system using another protocol while HART-IP is used for IDM and analytics.

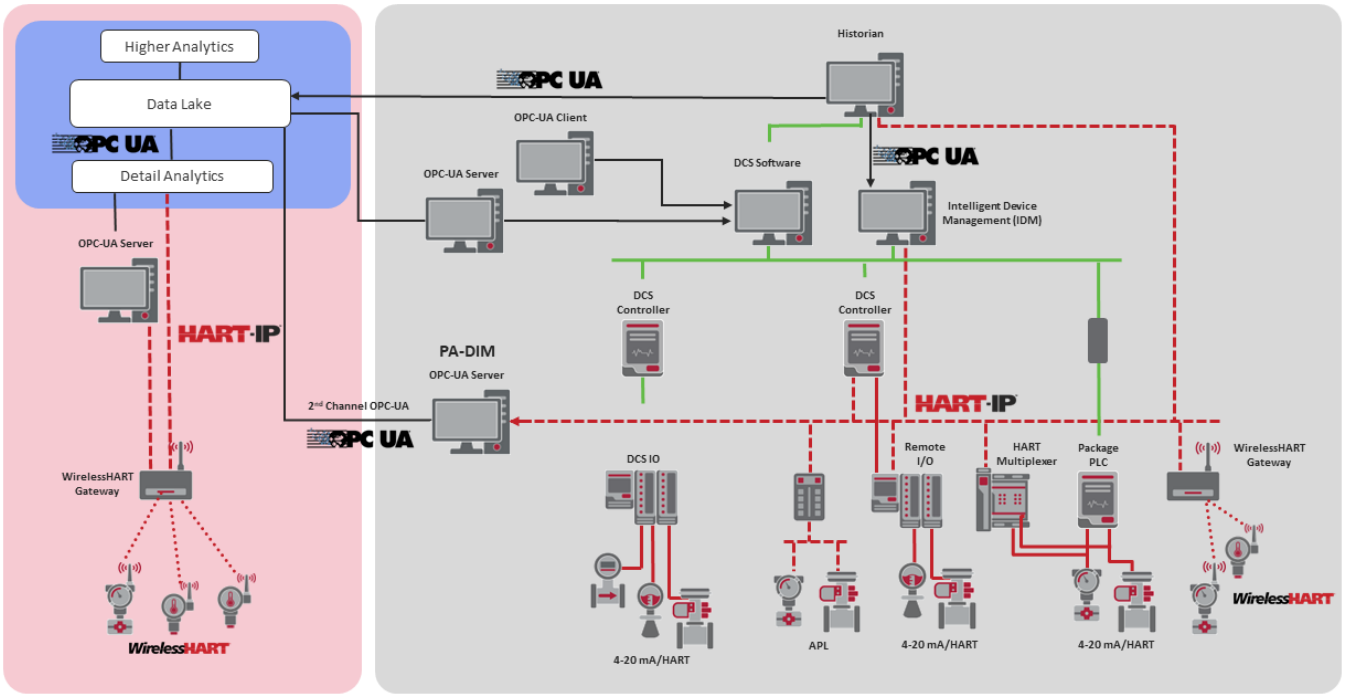
2.2.4 Cloud

Since HART-IP is based on IP it also runs across the enterprise network and the Internet straight into HART-IP compliant analytics and other apps running on a Virtual Machine (VM) in the cloud like Azure, AWS, or Google, without conversion to MQTT, AMQP, CoAP, or other messaging protocols thus avoiding loss of semantics associated with mapping data into MQTT *topics* or equivalent. This also avoids the additional hardware and software. This makes design for the Industrial Internet of Things (IIoT), cloud computing, and connected services business models very easy. IT/OT integration is easy and IT/OT collaboration is smooth. Nevertheless, an edge gateway can be used for the conversion of HART-IP to OPC-UA, MQTT, or other protocols for platforms or software that does not have native support for HART-IP.

2.2.5 NAMUR Open Architecture (NOA)

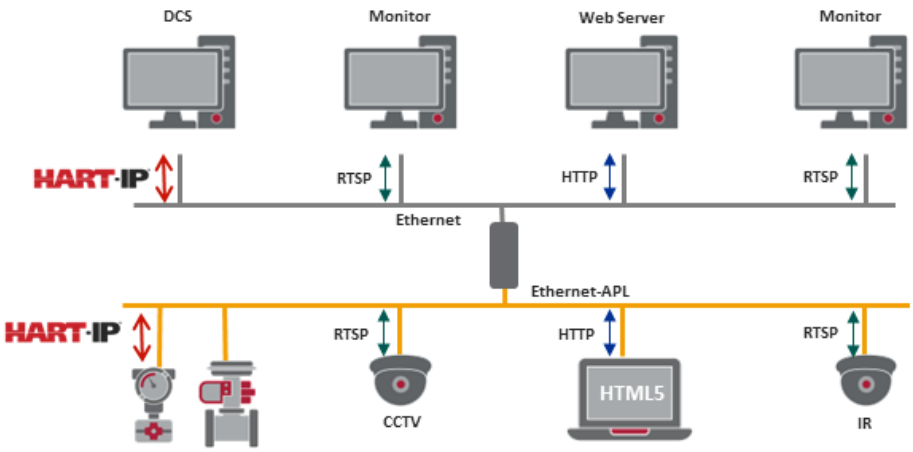
The NAMUR Open Architecture (NOA) in NAMUR recommendation NE175 defines interfaces between a Digital Operational Infrastructure (DOI), a second layer of automation for Monitoring and Optimization (M+O), and the DCS for Core Process Control (CPC). These interfaces are based on OPC-UA. The *second channel* is an interface to bring auxiliary measurements and other data from smart field instruments connected to the DCS for CPC, into the DOI to use for M+O. HART-IP is key to bringing data from 4-20 mA/HART and WirelessHART instrumentation

to the OPC-UA server for the second channel. That is, HART-IP and OPC-UA complement each other perfectly in this architecture. HART-IP in field instrumentation and supporting infrastructure, and OPC-UA in the larger devices and software above. A complete digital solution for Industrie4.0 and digital transformation can easily be designed.



2.2.6 Network Load

Ethernet networks are non-exclusive, shared by all kinds of devices and software using a plethora of different protocols at the same time. There may be a control system, transmitters, and control valves, but also IP video cameras, weighbridges, power meters, and HMI panels which have nothing to do with the control system all sharing the same network. Thus, the network traffic is not governed by the control system, but by the network switch. Calculating the network load of just the control system does not provide a complete picture. Rather, the network load shall be calculated based on the bandwidth used by all components.



2.2.7 Specifying HART-IP

Specify HART-IP version 2 backhaul network provides support for WirelessHART gateways, HART multiplexers, DCS, third-party SIS, and Ethernet-APL field instruments.

2.3 EASY SYSTEM IMPLEMENTATION

HART-IP makes software configuration easy for control system engineers and many existing DCS systems utilize HART digital data in the same manner as the current loop and with HART-IP your data flows throughout the system as it does for wired and WirelessHART. Interoperability is achieved thanks to EDD/FDI which also enables a device configuration database to be built offline in the engineering office before mobilizing to the site. The topology of underlying 4-20 mA/HART and WirelessHART devices is detected automatically in most systems.

2.3.1 Device Parameterization

HART instruments including Ethernet-APL field devices are very versatile and can be configured to operate in the desired way. Settings may include units, damping, sensor type, sensor connection, actuator type, etc. depending on the kind of device. Note that most kinds of HART-IP transmitters don't need a range to be set because there is no scaling to 4-20 mA, but it may still be possible to type in a range to get a reading in percentage. The range can be set for conversions, such as from differential pressure into flow or level measurement.

Thanks to EDD/FDI, the data in all 4-20 mA/HART, WirelessHART, and HART-IP instruments can be accessed and displayed automatically. It would be impractical to map all the setup/configuration, diagnostics, calibration, and auxiliary measurement data from hundreds or thousands of field instruments to Modbus/TCP or other protocols and then map again into some system and create graphics for it all. With HART-IP and EDD/FDI all that configuration work is eliminated. This makes system configuration a lot easier.

EDD/FDI also enables a device configuration database to be built offline in advance in the engineering office before mobilizing to the site. Doing this work in an engineering office is a lot easier than in the field at the site. Once at the site, the topology of HART-IP devices including field instruments as well as HART multiplexers and WirelessHART gateways with their underlying 4-20 mA/HART and WirelessHART devices is automatically discovered. Device configurations get downloaded automatically once the device has been connected to the system at the site. Configuring devices one by one on the bench the traditional way is also possible.

2.3.2 Link Publications

HART-IP devices, like transmitters, support multiple measurements. A HART-IP transmitter is configured for the required real-time measurements to be published for monitoring, control, and safety. A HART-IP valve is configured for which variable shall be subscribed as the setpoint. HART protocol utilizes request/response messages to change a setpoint, the response includes the request to confirm the change was delivered. Thanks to HART universal and common practice commands, the control system does not need an EDD/FDI file to do this.

2.3.3 Detail Analytics Software

Analytics applications closely tied to specific field instruments such as acoustic noise for steam traps and relief valves, corrosion and erosion, and vibration receive raw data from WirelessHART sensors directly through HART-IP without mapping through other protocols. HART-IP makes configuration of the linkage between applications and WirelessHART gateways from multiple vendors easy.

2.3.4 OPC-UA Server

A HART-IP OPC-UA server makes data in HART-IP devices available to OPC-UA clients like historians, data lakes, predictive analytics, Energy Management Information System (EMIS), Advanced Process Control (APC), Real-

Time Optimization (RTO), and many more software applications that don't have native support for HART-IP. Thanks to universal and common practice HART commands which are the same for all devices, and are preserved by the HART-IP protocol, a HART-IP OPC-UA server can make all the "*core parameters*" of 4-20 mA/HART, WirelessHART, and HART-IP Ethernet-APL instrumentation available automatically without having to manually configure desired data one by one. This makes system configuration very easy.

Get the data without the driver!

Process Automation – Device Information Model (PA-DIM)

NOA defines a second channel OPC-UA interface for M+O applications in the DOI to access intelligence in smart instrumentation on the DCS in the CPC. To make access to device information in OPC-UA servers from different manufacturers and different protocols consistent, NAMUR has defined a Device Information Model (DIM) for Process Automation (PA) devices such as field instruments. The information model defines a logical grouping of device information making it intuitive to browse the information from hundreds or thousands of field instruments from an OPC-UA client without the need for a DD/EDD/FDI Package. Again, thanks to universal and common practice HART commands and the HART-IP protocol, a HART-IP OPC-UA server can automatically organize all the "core parameters" of field instrumentation as per PA-DIM[2] without having to configure it manually. Again, very easy.

2.3.5 HART-IP Adapter

A HART-IP adapter acts as a proxy HART-IP connection for a single conventional 4-20 mA/HART device. That is, it allows a 4-20 mA/HART device to be connected to an IP network like regular Ethernet, Ethernet-APL, or Wi-Fi appearing just like a HART-IP device including publishing measured variables and subscribing to a valve setpoint output from a controller. The adapter is transparent to software and other devices because 4-20 mA/HART and HART-IP are both HART so there is no protocol conversion or manual data mapping involved. This is an easy solution during the transition period when a particular kind of device may only be available as a 4-20 mA/HART device and not yet available as an Ethernet-APL version. A HART-IP adapter can use Ethernet-APL, regular Ethernet, or even Wi-Fi. For instance, an Ethernet-APL adapter could be field mounted while an adapter for regular Ethernet could be mounted in an indoor marshalling cabinet. A strategically placed HART-IP adapter using an existing Wi-Fi network could bring in stranded field device data in a much simpler installation when compared to a WirelessHART network. Since it is HART-IP, the 4-20 mA/HART device's EDD/FDI file still works while the physical layer is different.

2.4 EASY SYSTEM INTEGRATION

HART-IP makes hardware and software integration, staging, and FAT easy for system engineers because it is all standard Ethernet. A HART-IP test client is available to test and make sure a HART-IP server can be reached and responds correctly.

2.5 EASY INSTALLATION

HART-IP makes site installation easy for instrument technicians because HART-IP uses regular Ethernet and two-wire industrial Ethernet-APL. Simply install and wire according to established standards. No RS485, no coax cable, and no special terminations.

[2] PA-DIM Specifications are available at https://www.fieldcommgroup.org/PA-DIM-Specifications

2.6 EASY COMMISSIONING

HART-IP makes site commissioning easy for instrument technicians and system engineers. The interchangeability enabled by universal and common practice commands, as well as device family commands, enable automatic configuration downloads for starting up the device. Easy identification thanks to tags. Conformance testing reduces the risk of issues onsite.

The control system handles most steps of the HART-IP device commissioning process such that it becomes transparent and easy for the technician to install or replace devices with like field instruments. Devices for functional safety will be commissioned in the same way.

2.6.1 Tag and Hostname

Commissioning a HART-IP device is primarily about first assigning its hostname which is made up of its process unit tag name and long device tag name. The hostname is the basis for clients like the control system to automatically find the server such as a field instrument, multiplexer, or gateway using DNS or mDNS without being manually configured for the device's IP address. This makes commissioning easy.

2.6.2 IP Address

HART-IP supports standard automatic dynamic address assignment to devices by the Dynamic Host Configuration Protocol (DHCP). This makes commissioning easy.

2.6.3 Bulk Download

HART-IP supports automatic bulk download of the full device configuration including security settings, pub-sub links, and parameterization for one or more devices from the control system or IDM software. This makes commissioning of large numbers of devices on a project very fast and easy. The settings are preconfigured into the system database offline in the implementation stage of the project and automatically downloaded when the device is connected to the system onsite.

2.6.4 Manual Commissioning

Alternatively, security settings, pub-sub links, and parameterization can be done for HART-IP devices one by one on the bench, via IDM, or in the field onsite with a portable tool like a laptop or tablet, just like 4-20 mA/HART devices are commissioned.

At the same time, HART-IP devices may have an embedded HTTP/HTTPS web server that enables viewing the configuration from a regular web browser. The web server defaults can be 'off' and 'read-only'. Any wireless interfaces on a device like Wi-Fi and Bluetooth can be shipped disabled by default. It is recommended to only use *secure* connections, such as the IDM or control system, to make changes to the HART-IP devices.

Devices can also be ordered and shipped preconfigured from the factory. Default parameter values are included in the FDI Device Packages.

2.6.5 Security Provisioning

For security, a HART-IP device such as an Ethernet-APL field instrument, HART multiplexer, or WirelessHART gateway is provisioned with its long device tag, process unit tag, TLS/DTLS password, Pre-Shared Key (PSK), as well as Syslog server hostname, port, and password. Multiple sets of security credentials are supported. Each client, like a software app, can have a different set of credentials to manage security with finer granularity.

2.7 EASY OPERATION

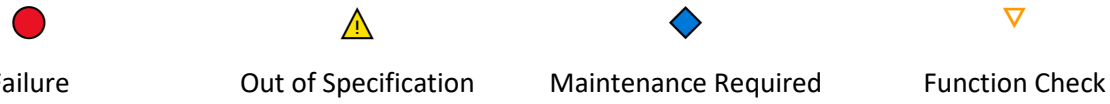
Once the HART-IP devices and software are commissioned, the operations with publishing and subscription of real-time data in control loops, and client-server reads and writes of other data, are transparent to users of control system console operators, but also to maintenance technicians and reliability engineers using equipment analytics, instrument engineers managing the devices, as well as integrity engineers monitoring corrosion and so on.

2.7.1 Process Variable Status

Process Variable status includes the measurement quality and limit condition of the value plus additional information which is supported by all HART technologies including HART-IP. That is, the process variable status is displayed consistently for all process variables regardless of source device manufacturer and model. This makes the process variable status easy to overview. Variable status flags may be used in operator graphics to indicate quality such as a good or bad measurement, or limited high or low, etc.

2.7.2 NAMUR NE107 Device Status

The standard NAMUR NE107 status signals to flag device diagnostics as a failure, out of specification, maintenance required, and function check are supported by all HART technologies including HART-IP. That is, the same status signals are displayed consistently for all devices regardless of manufacturer and model. This makes device health easy to overview. Simplified device status flags may be displayed in control system *operator* console graphics.



2.8 EASY MANAGEMENT

The familiarity with the HART family of protocols and regular Information and Communication Technologies (ICT) like Ethernet and UDP/TCP/IP makes HART-IP devices and software very easy to use.

2.8.1 Ethernet-APL Field Instruments

Plants are now designed with field instruments using Ethernet-APL instead of 4-20 mA and on-off signals. Ethernet-APL field instruments support HART-IP. This means Ethernet-APL supports the same functions and uses the same terminology as the 4-20 mA/HART and WirelessHART instruments which technicians have worked with for the last 30 years. Ethernet-APL instruments with HART-IP have the same familiar look and feel as the traditional HART devices they will be sitting next to for decades to come, making Ethernet-APL devices with HART-IP easy to manage.

2.8.1.1 Discrete Devices

HART-IP field devices include miniature remote I/O for discrete (binary) signals for switches, pushbuttons, solenoid valves, and signal lamps. HART-IP on-off valves and level switches connect directly to the Ethernet-APL network.

2.8.2 Device Management

HART-IP makes device management easy for instrument engineers and technicians. Device firmware updates are easy thanks to block data transfer. Devices from multiple manufacturers are displayed with a consistent look and feel thanks to EDD/FDI files. The system's device database is kept consistent thanks to configuration change

flags. Device diagnostics are displayed consistently for multiple manufacturers thanks to standard NAMUR NE107 status information provided by the devices. Thanks to HART-IP multiplexers and HART-IP pass-through, the plant's I&C team can take full advantage of intelligence in instrumentation and also on package units.

2.8.3 NAMUR NE107 Status Signals

The same NAMUR NE107 status signals, also known as DeviceHealth, explained for console operators in 1.7.2 are also displayed to *instrument technicians and engineers* in the IDM software.

IDM systems either retrieve the NE107 status from the device when the device flags more status is available or configure devices to publish a timestamped event notification when their status changes. The NE107 status signals are automatically displayed in the control system and IDM software and stored in the device for local access. IDM software and detail analytics applications, like control valve analytics, can automatically retrieve detailed diagnostics from the device on status change. HART process variables published with Command 9 include DeviceHealth with each response, making the NE107 status constantly available for instrument technicians to view or analyze.

Infrastructure components like Industrial Ethernet switches, particularly Ethernet-APL, may support NE107 and may also display the status locally using LEDs.

2.8.4 Network Management

HART-IP keeps network management easy for instrument and system engineers. HART-IP does not add administration burden as it shares the same network infrastructure as other protocols for other kinds of devices. Industrial Ethernet switches, including Ethernet-APL switches, routers, Wi-Fi access points, etc. support "State of the Art" Information and Communication Technology (ICT), standard SNMP for network monitoring using common network management software or the control system diagnostics utility and configuration through embedded webserver accessible by regular web browser for complete network administration. This makes network management easier. Network gear supporting backup and restore of the configuration is available. Access control prevents unauthorized access. Standard SNMP metrics are included. That is, networking gear need not be specially "HART-IP compatible"; regular industrial network infrastructure components are used.

HART-IP devices like HART multiplexers, WirelessHART gateways, and Ethernet-APL instruments have an IP address. HART-IP is supported over both IPv4 and IPv6, which can coexist. Future migration from IPv4 to IPv6 is thus possible. HART-IP supports automatic addressing via DHCP eliminating the need for manual address assignment.

HART-IP devices are identified by the freely configurable device tag and hostname. The device IP *hostname* is made up of the process unit tag name and the long device tag with a hyphen in between. For instance, a plant may have an isomerization unit with the process unit tag name "Isom", and in that plant unit there is a temperature transmitter with the device tag "TT1001". The IP hostname for this device now becomes "Isom-TT1001". In a system with a Domain Name System (DNS) server, devices can be found from any computer based on their hostname without knowing their IP address. HART-IP devices, being Ethernet devices, also have a MAC address. Instrument technicians do not have to deal with IP and MAC addresses by virtue of the IP hostname.

HART-IP uses the standard Precision Time Protocol (PTP) for clock synchronization with fallback to standard Network Time Protocol (NTP) when PTP is not available. PTP provides microsecond level time synchronization and NTP millisecond-level time synchronization.

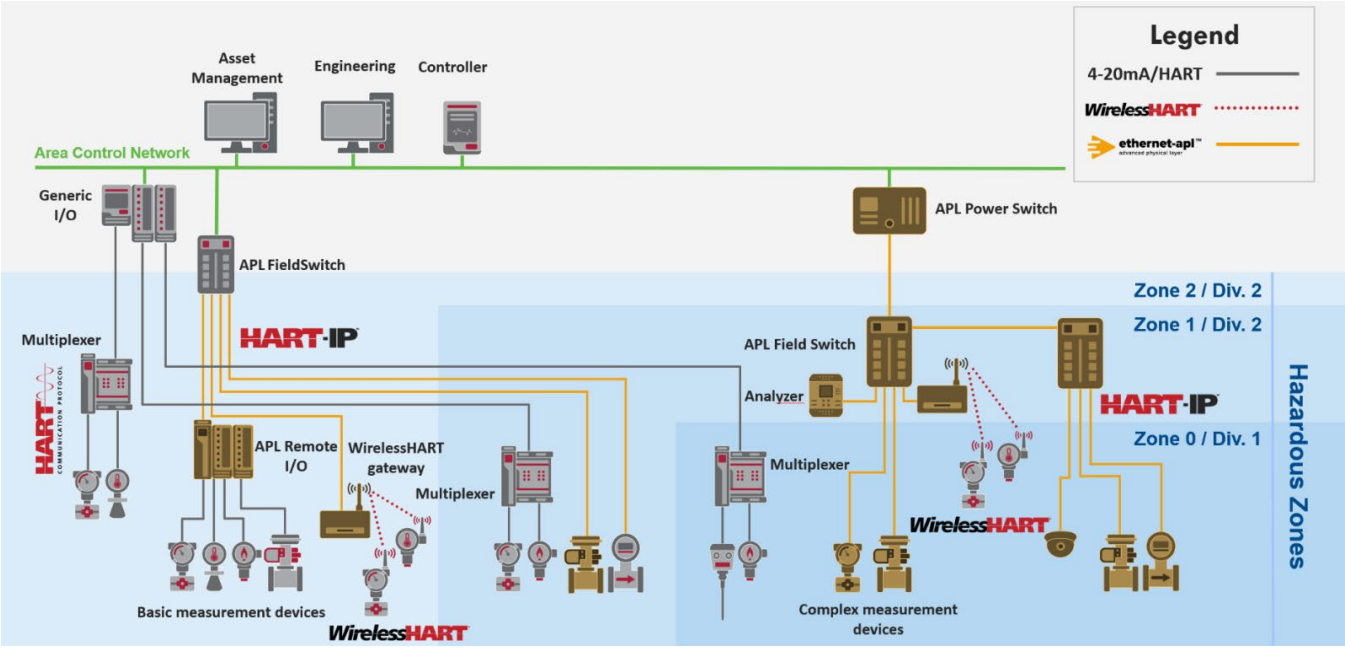
HART-IP has its own default port number (5094) making it possible to manage network communication traffic. HART-IP also supports Quality of Service (QoS) using DiffServ prioritization. Furthermore, real-time measurements and setpoint outputs to valves use UDP while non-real-time configuration and diagnostics use TCP. Thus, measurements and setpoint outputs to valves are not disturbed by device configuration and diagnostics traffic, during operation or commissioning, control system alarms, streaming video, or by setting higher and lower priority, etc.

2.9 EASY NETWORK TROUBLESHOOTING

HART-IP makes network troubleshooting easy for instrument engineers. The control system's network diagnostics application displays an alarm in case there are communication errors such as due to network overload. Simple ICT utilities like PING are supported in HART-IP devices. Common ICT utility troubleshooting tools like Wireshark support HART-IP also enabling experts to dive deeper into the details if necessary.

2.10 EASY MIGRATION

HART-IP makes migration easy for system architects. Plan to migrate from RS485-based HART multiplexers to Ethernet before they become obsolete and spare parts are no longer available. New HART multiplexers based on HART-IP support the same functionality or more and the same number of devices or more as their earlier RS485 counterparts. HART-IP is easy to deploy because it uses the existing Ethernet infrastructure already available for automation systems in most plants. New Ethernet networking can easily be added using the plethora of industrial-grade Ethernet hardware available. Existing IDM software can be upgraded to the latest version supporting HART-IP. With HART-IP, the migration from HART over RS485 to HART over Ethernet does not require any non-HART protocols to be introduced. This makes HART-IP a much easier migration path. Existing DCS can be upgraded to support HART-IP directly on their Ethernet interface cards to communicate with HART-IP devices such as instruments based on Ethernet-APL.



3 FIELD DEVICE INTEGRATION (FDI)

DD, EDD, and FDI are three generations of device integration technology used to integrate field instruments into IDM software. FDI is the preferred technology. The FDI technology is supported by all HART technologies including HART-IP. An FDI package is a file for each device type that is used by software that gives users access to details of field instruments such as configuration, diagnostics, calibration, and auxiliary measurements. The User Interface Description (UID) is in turn based on the Electronic Device Description Language (EDDL) specifications and is included in all FDI device packages. EDD is the descriptive meaning of each device, and the manufacturer determines the content and structure of the display of their device in the software, but the software determines the look and feel such as icons, colors, and buttons. Therefore, all information in all devices is made available as the device manufacturer intended, yet the look and feel of all devices from all manufacturers is consistent and independent of the manufacturer. This makes devices intuitive to work with. It also eliminates the need for data mapping and custom display creation.

4 SUMMARY

HART-IP is a simple, high-level application technology that is independent of the underlying physical layer. HART-IP operates with Ethernet as well as mesh or ring topologies. Similarly, HART-IP can run on Power over Ethernet (PoE) for such infrastructure and devices.

It’s fast, flexible, seamless, and secure.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