

HOW TO DEVELOP AND REGISTER A WIRELESSHART DEVICE



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1 INTRODUCTION

This technical paper provides a step-by-step guide for the development and registration process of a WirelessHART (IEC 62591) compliant field device. It also identifies the main decisions that must be made during the development process and helps the developer navigate these decisions.

Once the development and registration process are well understood, the developer can effectively plan the development project to reduce time-to-market and minimize the costs involved.

2 WHY CHOOSE WIRELESSHART?

The advent of the Internet of Things/Industrial Internet of Things (IoT/IIoT) has created an unprecedented opportunity to optimize process automation and expand the level of plant asset monitoring in a cost-efficient manner. The market has seen the emergence of a wide gamut of IoT/IIoT technologies with various use-cases. Due to the unique foundation of the original wired Highway Addressable Remote Transducer (HART) protocol, only the WirelessHART protocol truly addresses the connectivity, scalability, networking, device management, determinism, application layer modeling and security demands of the industrial process environment.

- **Communication reliability** – *self-organizing and self-healing wireless mesh network* allows communications to the gateway without line-of-sight to all devices and responds to changing interference conditions with no user-intervention resulting in 99.99% uptime in well-formed networks. Time diversity (TDMA), frequency diversity (hopping) and path diversity (mesh routing) ensure that all packets transmitted are received loss-free with minimal latency.
- **Interoperability** – *fully defined application layer* allows device manufacturers to utilize existing data structures (reducing product development demands) to ensure interoperability with existing control systems and data networks. There are currently over 15 registered device manufacturers and over 27 registered devices which are all fully interoperable over existing host networks from multiple manufacturers.
- **Cybersecurity** – *detailed, mandatory defense-in-depth security protocols* that ensure communications and networks are secured through a two-layer strategy. Data is authenticated hop-by-hop at the data link layer and encrypted and authenticated end-to-end at the transport layer. As security is not configurable, optional or vendor designed (as with most other IoT/IIoT protocols), end users are comfortable utilizing WirelessHART networks for process control and monitoring and critical asset monitoring.
- **Scalability** – *the self-organizing mesh network* allows for large networks of devices to be built without requiring line-of-sight to the gateways (as required by point-to-point protocols.) The determinism inherent in the protocol ensures messages are transmitted and received as per the application required

update rates to meet the rigorous reliability and latency requirements mandated by process automation, even as the number of devices increases.

- **Full Data Context** – all data points in the application layer have full context (including units, timestamps and health) maximizing the value of the data when used in analytics with little work by the device manufacturer or the end-user.
- **Publish-by-exception** – all field devices and adapters publish (push) process data based on process and device conditions. This ensures the data needed to control and monitor the plant and its assets is available when it is needed. It also cuts the energy needed in half to transport the process and status data compared to polling. This published data flows through the network gateway to control and monitoring systems associated with the plant.

WirelessHART is architected and designed to meet the rigorous requirements associated with industrial process automation environments. Unlike other IoT/IIoT protocols that are architected to cover a wider range of environments and applications, WirelessHART was specifically architected for industrial applications and their challenging environments. In a single plant, there are many applications that may have solutions from multiple vendors and technologies. WirelessHART was developed with interoperability and cybersecurity as cornerstones that enable multiple solutions to exist and communicate on the same network reliably and securely. The industrial environment often has a very high density and variability of obstructions and interference. This is addressed by WirelessHART with the self-organizing and self-healing mesh network which ensures reliable communication when line-of-sight to the wireless gateways is not always possible and may change over time.

WirelessHART is built on the **solid foundation of HART**, which is a widely deployed and well understood technology. Since the HART protocol was first developed as an open protocol in 1986, it has evolved to cover the wide range of applications found in the industrial environment. With an estimated 50,000+ networks operating worldwide, WirelessHART is simple to install in both new and existing plants and is easily the most common industrial wireless protocol in use today. For the developer, this can significantly reduce the amount of engineering effort and ensures compatibility with existing systems. For the end-user, it dramatically reduces the integration effort and risk involved and leverages the existing skills and knowledge of their personnel.

Unlike other IoT/IIoT standard technologies, it is a **holistic, top-to bottom, system wide standard** that defines all technical facets of the field instruments as well as supporting infrastructure devices including wireless connectivity, mesh routing, networking, security, application layer encoding, management as well as network provisioning. This allows the developer to focus on their core capabilities and fitting it into the existing structure, rather than diluting effort into non-core areas such as cyber-security, application layer definition and network management functions.

With an installed base of over 50 million devices, the ecosystem for HART and WirelessHART is huge. This provides many advantages as FieldComm Group offers in-depth support for developers and end-users. Not only are clear detailed Protocol Specifications available but so are training workshops and technical support. WirelessHART is a very deep protocol and both WirelessHART stacks and consultations are available from multiple vendors located in all world areas. The same Application Layer is used in HART and WirelessHART, which builds upon the know-how end users already have and love. The installed base of Plant Asset Management, control systems and maintenance tools are compatible with WirelessHART enabled instrumentation.

3 DEVELOPMENT AND REGISTRATION PROCESS QUICK REFERENCE GUIDE

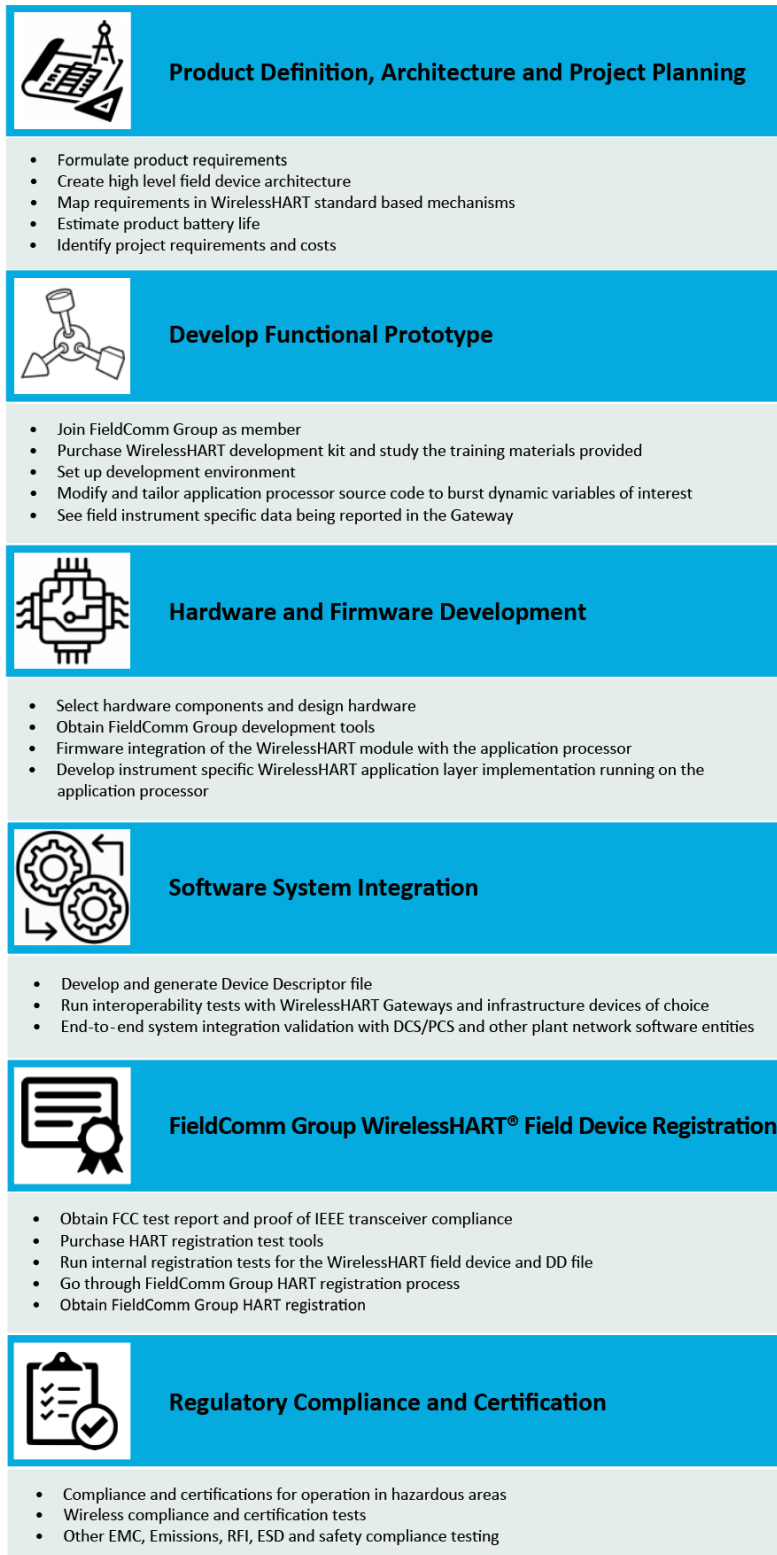


Figure 1: Development and Registration Process Quick Reference Guide

4 PRODUCT DEFINITION, ARCHITECTURE AND PROJECT PLANNING

Product planning is the fundamental first step that defines the vision for the product-to-be. The choices made here influence the product development costs. Three main considerations discussed in this section are functional requirements, architecture and project planning.

4.1 CREATE FUNCTIONAL REQUIREMENTS

A clear definition of requirements is essential and assumes a basic understanding of the features and mechanisms offered by the HART/WirelessHART standard. This will allow the developer to map the requirements into WirelessHART standard mechanisms. It will also allow the developer to fully utilize and leverage the powerful connectivity, reliability and security mechanisms present in the WirelessHART standard.

A clear definition of the requirements is of vital importance as it will influence the anatomy and architecture of the field instrument. It will also determine the optimal development approach that will minimize time-to-market.

When embarking on the journey of developing a WirelessHART field device, there are several important choices that the developer will have to make.

4.1.1 Device Type

WirelessHART products generally fall into three categories: field devices, adapters and gateways (see Table 1). The WirelessHART protocol has specific requirements for each product category with field devices being the simplest of the three. While this technical paper focuses on the development of a WirelessHART field device, it is also broadly applicable to developing a WirelessHART adapter.

Table 1 - WirelessHART Device Types

Device Type	Functional Description
Field Device	A WirelessHART field device combines wireless communications with traditional HART field device functions. Since the field device resides on the mesh network it also forwards/routes wireless packets on behalf of other network devices. The field device must include a HART 4-20mA maintenance port for commissioning and troubleshooting. The overwhelming majority of field devices are battery and/or energy harvester powered.
Adapter	The adapter connects to HART 4-20mA and to the WirelessHART mesh network. The adapter is essentially a single-channel remote I/O providing wireless access to "stranded" HART 4-20mA devices. Adapters typically get power from the 4-20mA loop.
Gateway	Gateways collect and relay data to/from the wireless mesh field network, manage the network devices and provide connectivity to the plant network. The Gateway typically aggregates four different functions. Access Point: Provides wireless connectivity between the field mesh network and the Gateway.

Device Type	Functional Description
Gateway	<p>Network Manager: Manages all connectivity and facets of the field devices and adapters.</p> <p>Gateway: Responsible for application layer connectivity between the wireless field mesh network and the plant network.</p> <p>Security Manager: Manages the security credentials (e.g., keys, identities) and monitors the status of the network security.</p>

4.1.2 Application Layer Functionality

Application Layer Functionality is the definition of the application specific behavior and functionality of the device that is being developed. This functionality includes (but may not be limited to):

- What the inputs and outputs of the device are
- How will the device be commissioned, configured and calibrated
- Can standard HART commands be used to configure/operate the device or must device specific commands be created to enable functionality
- Will the device need to provide any external alarms

Prior to defining the field device’s application specific functionality, it is important to understand the underlying HART/WirelessHART standard based data models and command sets.

Dynamic Variables

The HART standard relies on a bursting (publishing) mechanism where dynamic variables are transmitted periodically with a configurable periodicity. WirelessHART supports bursting of four variables namely a PV (primary variable), SV (secondary variable), TV (tertiary variable) and QV (quaternary variable). These variables can be reported to the WirelessHART Gateway via wireless data packets. Additional variables can also be sent via the bursting mechanism, with field devices often supporting multiple burst data streams where different variable sets are being sent with different periodicities. The bursting rates are configurable and the supported reporting rates are 1, 2, 4, 8, 16, 32 seconds or 1 to 60 minutes depending on the Network Manager that is managing the WirelessHART field mesh network.

The HART client-server data model is supported over the wireless communication channels where the Gateway can read or write parameters via a client-server type data interaction. The data exchange is acknowledged end-to-end between the client and the server devices.

Command Sets

HART supports various command sets that target different functional facets of the field device. All commands are designed so that generic host applications can use the device without need for EDDs or device-specific drivers.

Table 2 - HART Command Sets Overview

Universal commands	Used to read device identifiers, device variables as well as configure various HART parameters. All HART-Enabled Field Devices must support all Universal Commands as specified.
Common Practice commands	A broad set of commands applicable to many field devices. Primarily focused on field device calibration, configuring ranges as well as reading and writing other configuration parameters.
Non-public commands	Used by manufacturers during the manufacturing of the field device itself and should remain confidential.
Wireless Commands	Used to by WirelessHART field devices, adapters and networks to manage every aspect of the wireless communication, including provisioning, bandwidth allocation, security, wireless co-existence, health reporting and more.
Device Specific commands	Provide functions that are unique to a particular type of field device.

When developing a field device, the developer must map the desired application layer functionality of the field device to the various commands. If the field device includes specific functionality that is not available through the commands defined by the standard, the developer will need to map this unique functionality in *device specific commands*. To maximize interoperability, it is highly recommended to try to map all the functionality of a device to the standard commands and reserve device specific commands to truly unique device functionality only when necessary. The list of commands available can be found in the Command Summary Specification and the other detailed command specifications, which are available on the HART Protocol Specifications page on the FieldComm Group Website.

The outcome of defining the application layer functionality of the field device should be a map of commands that the field device will support to meet the functional requirements desired.

4.1.3 Sensors/Actuators

The choice of sensors or actuators for the field device is critical. First, the sensor/actuator must be powered, measured or controlled. This dictates the interface circuitry and ripples on through the product requirements.

Second, the sensor/actuator is not powered continuously. This is a major difference compared to traditional instrumentation. Often developers have carefully validated models characterizing sensor/actuators over time, temperature and process conditions. These usually assume the sensor/actuator is continuously powered. Since WirelessHART devices sleep most of the time the sensor/actuator is now intermittently powered. Therefore sensor/actuator selection is different and faces new challenges where development of new algorithms may be needed.

Managing the sensor/actuator can consume up to 1/2 of the power budget for a wireless device.

4.1.4 Powering the Wireless Device

The power source for a field device can be line power, battery power, energy harvester or any combination of these.

- The vast majority of WirelessHART devices are battery powered to provide the end-user with the easiest and most cost-effective installation.
- If the developer opts for a line-powered device, power consumption and energy budgeting are not a concern, but more stringent noise immunity requirements should be considered. The cost of installation associated with power wiring should also be considered.
- Energy harvesters can also be used but they typically only augment battery power and they can raise product costs. When opting for energy harvesters the same design considerations apply as for battery powered devices.

The vast majority of commercially available WirelessHART field devices are battery powered and this section will focus on battery powered design issues. Battery life requirements vary from 2 – 10 years with end users insisting on prolonged battery life to minimize the cost and disruption to the process associated with battery replacement. Battery replacement concerns are even more accentuated when the field device operates in hazardous, incendiary and/or remote areas.

When opting for battery power the aggregate power consumption of the field device is vital since it will determine the battery life of the field device.

4.1.4.1 Battery Power

The battery must be chosen to meet the target battery life. Consequently, environmental impacts (e.g., installed temperature variations), affect the chemistry of the battery and the device power consumption must be analyzed/modeled. Most field device developers opt for high-density battery chemistries such as lithium-thionyl-chloride or other lithium-based chemistries.

The topology of the on-board power supply will be determined by factors such as battery pack voltage and chemistry. The on-board power supply can be of buck or buck-boost type depending on battery life requirements as well as the target COGS of the field device.

Battery leakage/self-discharge and power supply efficiency/regulation are important factors in power consumption and thus battery life.

If the battery can be replaced, then the associated mechanics and safety must be carefully considered and designed.

4.1.4.2 Power Consumption

Batteries only hold so many coulombs and understanding the coulombs needed for the different field device operations is key to estimating battery life. Device operations affecting battery life include:

- Managing the sensor/actuator - making process measurements
- Publishing process and status data
- Plant Asset Management and configuration changes
- Network Management (advertising, forwarding packets, etc.)
- Servicing the maintenance port

- Power supply overhead

Each of the coulomb requirements for these should be characterized and used as inputs to the battery life model. Some of these operations are under the control of the device developer while some are controlled by the user and Network Manager.

The communication schedule of the field device is the main determining factor for the battery life of the field device. Field devices spend most of their time in deep, battery conserving sleep to prolong battery life. They only wake up when they need to transmit or receive a data packet or engage in measurement/monitoring/control.

The wake-up schedule is determined by the Network Manager based on several factors:

- How often will the field device publish process and status data or be awake to receive acyclic communications (e.g., from Plant Asset Management).
- If an actuator, how often will it receive control data.
- How often must it service the mesh network (e.g., route other packets, ping neighbors, advertise, etc.).

The actual communication overhead could consume as much as half the power budget. Radio and processor technologies are rapidly improving so the requirements of this power consumer are declining continuously.

Using this information, the developer should create a battery life model for the field device that includes all these considerations to ensure that the marketed and advertised battery life of the field device is met. This model should include "typical" operating conditions and publishing frequency.

The communication and measurement/control frequency are controlled by the user and cannot be limited by the device itself. All WirelessHART devices equally face this challenge. Fortunately, users are becoming savvier about the way they are using WirelessHART devices and have a good understanding that additional data costs power/battery usage.

4.1.5 Operation in Hazardous Areas

An important design decision is related to the environment that the field device will need to operate in. Many field devices engaged in process monitoring and control will operate in hazardous areas with the potential presence of explosive gases, incendiary liquids and/or dusts.

If the field device is intended for operation in hazardous areas the developer will need to define the hazardous classification that the field instrument will need to be compliant and certified to. Once these requirements are well defined, the developer can then opt for either an explosion proof or an intrinsically safe design and certification approach.

Intrinsically safe devices rely on the principle that the field device is not capable of causing an explosion. Explosion proof field devices rely on the principle that should an explosion occur, it will be contained within an enclosure. Both approaches have advantages and disadvantages from a design and certification complexity as well as the impact on the final COGS of the field device.

When designing for operation in hazardous areas, it is important to consider how the user will replace the battery and access the wired HART maintenance port terminal.

4.2 IDENTIFY FIELD DEVICE ARCHITECTURE

Most field device suppliers are domain experts on specific types of sensors (monitoring) or actuators (control). WirelessHART expertise will be needed by the product developers to support their customers and complete the product development. But developing a WirelessHART stack itself is a complex and resource intensive effort that is risk/cost prohibitive for most instrument developers. Consequently, most WirelessHART field devices use a two-processor architecture as shown in Figure 2. The application processor and the wireless module are connected via a serial interface.

The figure below depicts the typical anatomy and architecture of a WirelessHART field device.

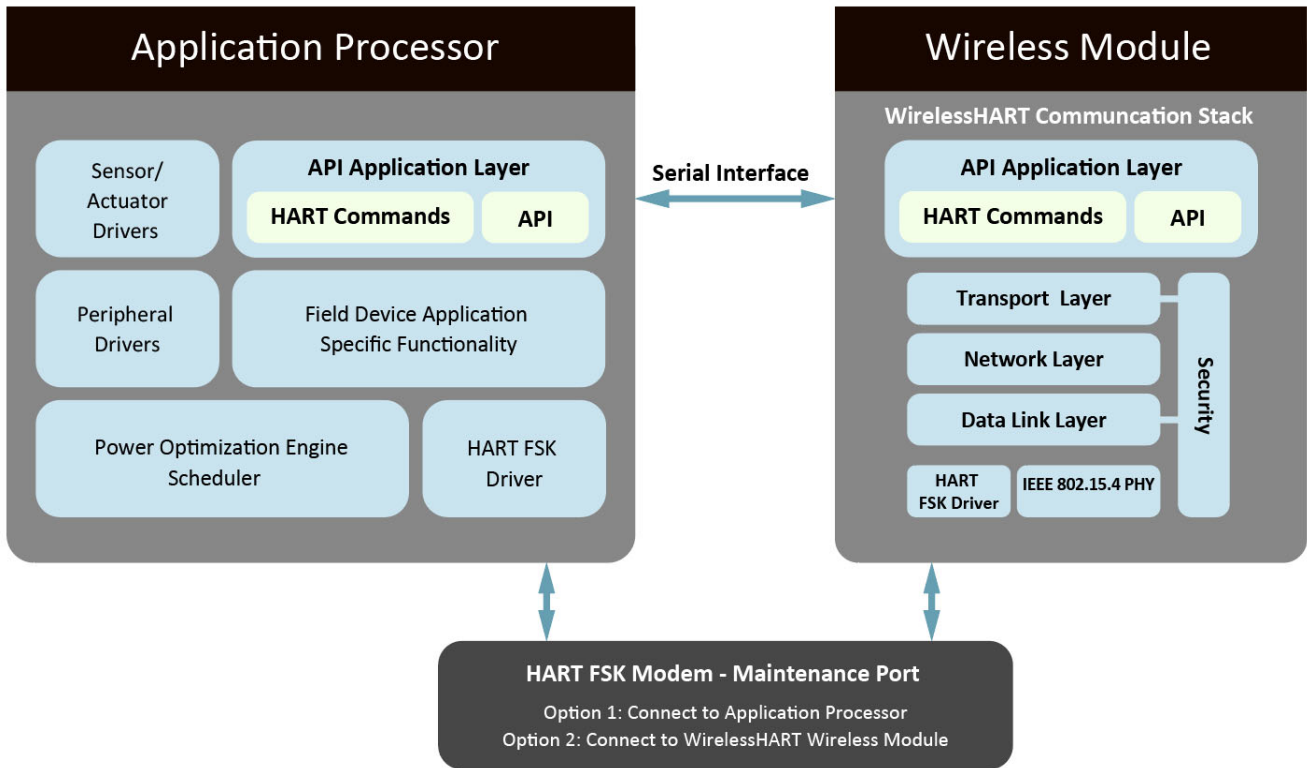


Figure 2: Field Device Architecture

This approach has many benefits with the main ones listed below.

- Wireless modules provide the communication stack that handles about 50 wireless commands.
- It reduces the in-house wireless expertise needed to develop a WirelessHART field device. Wireless modules have typically already gone through modular wireless testing, compliance and certifications and are ready to be embedded and integrated in field devices. The need to acquire expensive RF engineering equipment and conduct measurements is avoided.
- Wireless module pre-approvals by FCC, ISSED, ETSI, etc. help reduce time-to-market.
- Wireless modules provide serial command line interfaces to which the developer can connect an application processor that is responsible for the application functionality of the field device.

- Development kits from the wireless module vendors typically provide software/firmware frameworks that speed up the development process and shorten the product time-to-market.
- Developers can focus on their core competency and develop the application processor hardware and software.

The typical responsibilities of the wireless module and application processor are summarized in Table 3.

Table 3 – Responsibilities of Entities

Application processor	Wireless module
<ul style="list-style-type: none"> • Implements the HART Application Layer • Connects and manages the device's sensors and/or actuators • Publishes process and status data to the Gateway • Shares responsibility for a few WirelessHART commands with the wireless module • Supports the maintenance port • Note: some commands must be passed through to wireless module • Monitors battery-life, estimates days of battery remaining 	<ul style="list-style-type: none"> • Implements the WirelessHART command set • Complies with IEEE 802.15.4-2.4GHz requirements • Precise time management needed by the TDMA Data-Link Layer • Ensures all communications are secure • Routes all packets per instructions from Network Manager • Reports network health and RF health as measured by the field device • Joins the network, manages connection with the mesh network and the field device's neighbors

4.3 THE PROJECT TEAM

Developing a WirelessHART field device requires multi-disciplinary engineering teams. It requires expertise in the following disciplines:

- A solid understanding of the HART and WirelessHART protocols
- RF expertise and engineering
- Hardware engineering (embedded systems, sensors, actuators)
- Firmware and software engineering
- Software engineering for the development of the EDD files or other files needed to integrate with entities that reside on the plant network
- Compliance and certification expertise for hazardous locations, wireless communications, EMC and other safety compliance testing

The developer staff may be allocated to one or more of these areas or elements of the project team may be outsourced to companies and teams that have expertise and experience in developing HART and WirelessHART field instruments. For a list of providers of development and engineering services please visit: <http://go.fieldcommgroup.org/HART-developers>

4.3.1 Training

The project team will need training and support. Several sources are available including the wireless module supplier/partner and the FieldComm Group. The FieldComm Group provides dedicated and specific training and technical support on the HART and WirelessHART protocols including:

- Protocol Specifications and technical papers
- Developer/engineering workshops
- Technical support

4.3.2 Tools

Various development and testing tools will be required. These include tools from the traditional embedded device supply chain, the wireless module supplier and the FieldComm Group. Tools available from the FieldComm Group include: HART and WirelessHART Test Systems, Wi-Analys, FDI Device Package IDE, FSK PHY Test Kit and HART-IP Clients.

HART Physical Layer Test Kit. This tool is used to assess HART Frequency Shift Keying (FSK) Physical Layer conformance. In addition to this kit, it is recommended to purchase a bipolar power supply for impedance and noise sensitivity testing on the maintenance port.

HART Test System. The HART Test System is a complete communication development and testing package for HART 4-20mA (FSK) field devices. The HART Test System includes an interactive, programmable host application that can be used for ad-hoc communication with the device early in the development process (via FSK). Included is the univ-ht.qas script (source code) that demonstrates how a Universal Command application can be supported using HART Test System tooling.

WirelessHART Test System. The WirelessHART Test System includes a simplified Gateway and Network Management used for testing. It also allows for ad-hoc communication to the field device throughout the product development process (via the wireless channel) using the same techniques used with the HART Test System.

Wi-Analys. Wi-Analys is a WirelessHART packet sniffer and network analyzer. Wi-Analys simultaneously captures and timestamps communication on all sixteen IEEE 802.15.4 frequency channels in the 2.4 GHz frequency band. WirelessHART communications are extracted then deciphered and parsed for easy review and assessment.

FDI Device Package IDE. The FDI Device Package IDE is used to develop and test FDI Device Packages and EDDs. Your product's FDI Device Package (and EDD) enable immediate, complete support of products in the large installed base of HART-enabled Plant Asset Management Systems, handhelds and other end-user systems/tools.

HART-IP Clients. FieldComm Group has posted a HART-IP Client on GitHub. These are free tools that (among other things) enable communications with WirelessHART field devices via commercial HART-IP Gateways. The clients include many standard commands and allow any command (e.g., device-specific ones) to be manually constructed and sent.

The HART and WirelessHART Test Systems include HART-IP Servers for connecting to Token-Passing or WirelessHART networks. The HART-IP Clients can connect to the test appliance and communicate with the field device being developed via HART-IP servers.

4.3.3 Registrations and Certifications

Many registrations and certifications are needed by the field device. These include IS/Ex (hazardous area), wireless communication, EMC and other safety compliance testing.

The FieldComm Group operates a Quality Assurance / Quality Control (QA/QC) program for WirelessHART field devices. It is based upon standardized test requirements and specifications developed by its membership. These test requirements ensure products will interoperate with other WirelessHART devices and HART-enabled applications. The core objective is to reduce/mitigate (not eliminate) the need for field service and technical support by the device developer to end user. Field device registration testing and assessment is comprehensive and robust. Please contact FieldComm Group for more information.

4.4 ESTIMATE PROJECT DURATION AND COSTS

Once the functional requirements and architecture have been finalized the duration of the project and the costs must be estimated.

The duration, effort and cost associated with each project phase should be estimated to get a clear picture of the aggregate timeline and costs.

5 DEVELOP FUNCTIONAL PROTOTYPE

The next step in the development process is to develop a functional prototype. Developing a functional prototype is strongly recommended both to mitigate risk and for developers to begin climbing the WirelessHART learning curve. Acquiring a WirelessHART development kit from the selected wireless module vendor is a significant project accelerator.

WirelessHART development kits include various training materials as well as engineering documentation related to the integration of the WirelessHART module, and all the components required to set up a simple WirelessHART field mesh network. This includes wireless modules, development boards and a WirelessHART Gateway that can be used to set up a WirelessHART network. Once the developer is familiar with the operation of a WirelessHART mesh network the actual prototyping work can begin.

The developer can set up the development environment using the Integrated Development Environment (IDE) of choice. Once the development environment is set up, the user can load the application processors source code and compile it. The developer can start tailoring the application processor source code provided to meet the requirements of the field device that is being developed.

The application processor source code provides a framework for developing the HART Application Layer including Universal and Common Practice Commands. Placeholders for linking application processes like performing sensor measurements and control may also be supplied. Consequently, the prototype can be expanded and used as a research vehicle for developing sensor signal conditioning, signal processing and other key elements specific to the product envisioned. The prototype can provide valuable direct feedback for the subsequent Hardware and Firmware development.

The developer can map parameters of interest in the four dynamic variables (PV, SV, TV, QV) and use the burst mechanism to see these variables being reported in the Gateway. At this stage, these parameters can be hardcoded values or real values obtained from sensors and/or actuators connected to the application processor.

The developer can also send various commands to the field device prototype to become familiar with the various types of commands and their associated functionality. Preliminary power consumption and current draw measurements can also be made for the purpose of building a power model for battery powered instruments.

6 HARDWARE AND FIRMWARE DEVELOPMENT

6.1 HARDWARE DEVELOPMENT

Various decisions will have to be made at the start of the hardware development and engineering effort. The complexity of the hardware design process will vary depending on the device's intended function – whether it would need to be explosion proof or intrinsically safe. Once all components are selected, the developer can design the field device circuitry. In addition to the hardware decisions based on the core device functionality, the following components will also need to be considered.

Battery

The developer will have to choose a battery that has enough capacity to meet the power budget required by the desired battery life. The battery chemistry is an important consideration, as it will dictate the topology and efficiency of the power supply circuitry.

Maintenance Port

All end users have HART-enabled handhelds and the maintenance port must interoperate with these user tools. An actual HART FSK modem IC is the key element in the maintenance port. It will be in deep sleep mode until a carrier is detected. The maintenance port must wake up when a carrier is present and receive any communications successfully. HART has detailed requirements for maintenance ports that must be met to ensure a high quality user experience.

Antenna

The WirelessHART field devices must be able to transmit with an output power in the -10 dBm to +10 dBm range (10 mW). Hence, the antenna will have to be chosen based on the specifications of the wireless module selected. The antenna propagation patterns and proof of compliance to IEEE 802.15.4 are required during the FieldComm Group registration process.

Assessing the hardware design

When a prototype of the hardware is available, it is highly recommended to run HART maintenance port compliance with the HART Test System. The FieldComm Group will confirm compliance as part of the registration process.

Wireless range tests and In-house (or wireless test-house) wireless compliance testing are also recommended to ensure that the surrounding circuitry does not affect the performance and modular certification of the wireless module (for example, spurious emissions, harmonics and sensitivity).

6.2 FIRMWARE DEVELOPMENT

Prior to starting the firmware development process, the developer should contact the FieldComm Group and request an assigned Manufacturer ID and Device ID as the Device ID will be required during the development of the Device Descriptor file. Requests for IDs are accomplished via the technical support portal.

The firmware development process is focused on two main facets:

1. Integration of the wireless module with the application process, which is done in accordance with the API documentation provided by the wireless module vendor.
2. Developing the field device specific application layer functionality on the application processor. The sensing or control circuitry and parameters of interest will need to be mapped to HART commands and mechanisms.

Once the integration of the wireless module and the application processor development is completed, the developer will have to focus on the power consumption of the entire field device. During this development phase the developer will fine tune the current draw and overall power consumption of the field instrument. Since both the application processor and wireless module should spend as much time in sleep mode as possible, fine tuning and coordinating all of the field device's internal entities, including the HART maintenance port will have a significant impact on the battery life of the field instrument.

The FieldComm Group offers various tools that are invaluable during the development process.

The WirelessHART Wi-Analys tool is a WirelessHART packet sniffer and network analyzer that is very useful during the development and debugging process. Wi-Analys captures and deciphers WirelessHART communications enabling product development and compliance assessment. Wi-Analys includes a FieldComm Group patented 16-channel IEEE 802.15.4 receiver that captures radio communications on all frequency channels simultaneously.

7 SOFTWARE SYSTEM INTEGRATION

A HART Device Descriptor file (DD file) and FDI Device Package are required and submitted as part of the FieldComm Group HART registration process.

The DD file enables the field device to interact with the WirelessHART Gateway as well as other software entities running on the plant network (DCS, PCS, configuration and diagnostics software, historians, etc.). The DD file models all the capabilities of the field device, including:

- Commands supported
- Configuration parameters
- User interface

A comprehensive and well-organized DD file is critical to the successful development of a WirelessHART device as it will dictate the way end users interact with it and should be done in parallel with the firmware development process. The DD file is developed and modeled using Data Definition Language_(DDL). The DD developer must have expertise in the operation, behavior and capabilities of the field device for which the DD is being written, to ensure all required functionality is configured correctly.

The use of standard methods and commands is encouraged; however, device specific commands are also allowed and are required in some cases to activate certain features on the device.

An Enhanced Device Descriptor (EDD) provides graphical elements that stand apart from the traditional hierarchical text menus. A good DD design will greatly simplify device configuration and not overwhelm the user looking to perform a specific task.

The Device Descriptor can be ported for use on a variety of host systems and integration testing with various entities including asset management packages as well as handheld configuration tools are highly recommended. It is a good idea to purchase the respective tools or simulate the Device Descriptor on a virtual device as a part of the development process. Several manufacturers provide virtual hosts and test kits so that the Device Descriptor can be evaluated on the target platform.

The FieldComm Group offers all the software tools needed to develop and validate a DD file. The FDI Device Package IDE makes writing, running and testing of FDI Device Packages and EDDs easier and more efficient by providing a single tool for development and testing.

8 FIELDCOMM GROUP WIRELESSHART® FIELD DEVICE REGISTRATION

A core objective of the FieldComm Group is to assist in the development of compliant, interoperable HART-enabled products. The member-developed protocol specifications are the first step. They are detailed and designed to ensure interoperability. The FieldComm Group also offers a QA/QC program to further ensure successful device operation and integration into plant systems.

WirelessHART devices successfully completing the standardized QA/QC program become "HART Registered". This badge indicates the field device meets all the protocol requirements needed for proper field operation as well as interoperability with other WirelessHART field devices and host systems.

The figure below provides a snapshot of the steps that are part of the FieldComm Group HART registration process. Utilizing the FieldComm Group QA/QC resources should accompany other steps in the development process.

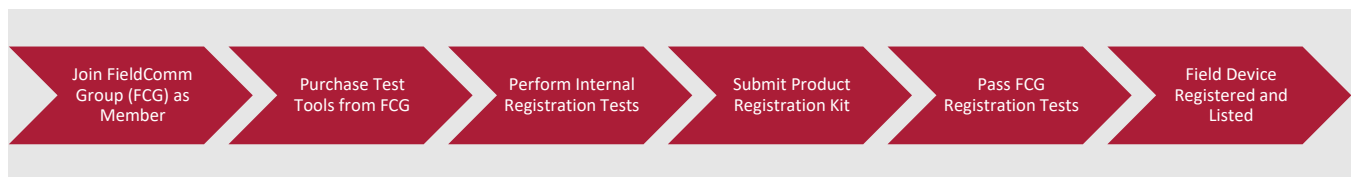


Figure 3: FieldComm Group HART Registration Process

➤ Step 1: Join FieldComm Group

Joining the FieldComm Group as a member has many benefits. It provides an opportunity to contribute to and shape future IIoT technologies. It also provides discounted pricing to a large gamut of training, development, compliance testing and registration tools as well as access to the Protocol Specifications and standardized test plans (specifications). Members also have priority access to FieldComm Group's technical support team.

➤ **Step 2: Purchase Test Tools**

The FieldComm Group offers a complete suite of protocol-specific tools to help in product development. They are extremely useful during the development process as they enable ad-hoc field device testing and ensure implementation is correct during every stage of the development process.

The test tools also include test automation. The test automation is run on top of the tools and align with the member-developed test specifications.

➤ **Step 3: Perform Internal Pre-registration Testing**

The developer must perform Quality Control of the field device. QC includes both field device-specific testing and using the test automation provided with the FieldComm Group supplied tools. Table 4 below lists and describes the various QC tests the developer should perform and are required to obtain FieldComm Group HART registration.

During the internal pre-registration testing phase, the developer should collect all test logs and results since they must be submitted as part of the registration package.

Table 4 - Compliance Assessment

Test	Description
Physical Layer Testing	Confirms FSK maintenance port compliance
Data Link Layer Tests	Tests the Token Passing DLL used by the maintenance port
TDMA Data-Link and Mesh Network Layer (TML)	Assesses WirelessHART mesh network compliance. While the bulk of these are applicable to the wireless module there are some requirements that must be fulfilled by the application processor.
Universal Command Testing	Tests Universal Commands over both the maintenance port and the wireless channel.
Common Practice Command Testing	Tests the Common Practice Commands over both the maintenance port and the wireless channel.
System Level Tests	Ensures interoperability and proper long-term reliable operation with commercial products (devices and Gateways). The System Level Test must be performed in a multi-hop multi-vendor mesh network.
FDI Device Package Testing	Confirms that the EDD complies with all EDDL and HART Protocol Requirements. Ensures the FDI Device Package is secure, well-formed and meets all FDI requirements.

The TML and System Level tests are arduous and require considerable WirelessHART knowledge. This QC step can be contracted to the FieldComm Group for a nominal fee. It is highly recommended to have the FieldComm Group run at least the System Level tests on behalf of the developer.

➤ Step 4: Submit Product Registration Kit

Once all internal pre-registration tests have been successfully passed, the developer will collate the FieldComm Group registration package. The registration package consists of:

- All test logs and results
- Supporting documentation for functional and standards compliance
- Passed wireless certifications
- The DD file and FDI Device Package

Proof of Wireless PHY compliance must also be provided, including:

- IEEE 802.15.4 compliance test results
- Wireless compliance test results (FCC, ETSI etc.)
- Antenna radiation patterns

➤ Step 5: FieldComm Group Registration Testing Phase

The official registration process is triggered by the submittal of the registration package and a purchase order that lists the type of registration testing being requested. Upon receipt, the FieldComm Group team will schedule a test campaign and inform the developer of the start date of the test campaign. Two field instruments will have to also be submitted to be used as “Devices Under Test” (DUT’s).

The developer must promptly respond to any requests received from the FieldComm Group team during the testing process.

➤ Step 6: Field Device Registered and Listed

Once the FieldComm Group confirms that all registration tests have been successfully passed and all requirements have been met, the DD file will be sent out for testing with various host systems.

The field device will be registered and listed in the FieldComm Group repository and the DD file and FDI Device Package will be available for download on the FieldComm Group website (fieldcommgroup.org).

9 REGULATORY COMPLIANCE AND CERTIFICATION

9.1 OPERATION IN HAZARDOUS AREAS

If the field device is designed for operation in hazardous areas, it will also need to go through various compliance tests and certification processes. Field devices that need to operate in hazardous locations are typically certified to operate in areas classified as Class 1 Division 1 and/or ATEX Zone 0 areas for various groups of gases, liquids and incendiary dusts/fibers as needed.

9.2 WIRELESS CERTIFICATIONS

Any wireless device also must be compliant to various wireless regulations and obtain certifications in various countries and regions of the world where it will be used.

The WirelessHART wireless module will typically already have modular wireless certifications for operation in various countries.

In the USA and Canada, additional product level wireless compliance testing is needed beyond the FCC Part 15 modular certification of the wireless module. The product will have to pass FCC/ISED Part 15, Unintentional Radiators, Subpart B, Section 15.101. These compliance tests ensure that the wireless module's supporting and afferent circuitry did not cause the already certified wireless module to operate outside the boundaries of its modular certification.

No additional product level wireless compliance testing of certifications are needed in other regions and countries of the world, such as the EU and Japan once the wireless module is certified (EU – ETSI 300 328, Japan Certification Ordinance Article 2-1-19). The developer will have to conduct internal measurements and provide a compliance statement stating that the product relies on the wireless module's modular certification.

9.3 ADDITIONAL REGULATORY COMPLIANCE AND CERTIFICATIONS

The field device will typically also have to pass various additional EMC, RF immunity, ESD and safety compliance testing.

It is recommended that the product also be compliant and certified to:

- EN 301 489-1 V2.1.1
- EN 301 489-17 V3.1.1
- EMC emissions compliance per EN55032
- ESD compliance per ESD 6100-4-2
- RF Immunity per EN6100-4-3
- Safety compliance testing per LVD EN 60950-1:2005 +A1:2009 +A2:2103 and EN62368

10 CONCLUSION

This tutorial presents a step-by-step approach for the development process of a WirelessHART field device. It also identifies the main decisions that must be made during the development process.

Developing a WirelessHART compliance and registered field device does not have to be a daunting endeavor. Once the development and certification process are well understood, the developer can optimally plan the development project to reduce time-to-market and minimize the costs involved. Once the device is designed, developed and certified, the developer will have access to more existing industrial wireless field device networks and host systems than any other IIoT protocol and will benefit from the trust and familiarity that end-users have with the WirelessHART Protocol.

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12 REFERENCES AND RESOURCES

1. Romilly Bowden, HART® Technology – A Technical Overview, ISBN 9781549862274
2. Gerrit Lohmann, Wireless Technologies – WirelessHART® - A Technical Paper
3. Emerson, Industrial IoT Devices: WirelessHART® and 5G
4. FieldComm Group, WirelessHART Bootcamp
5. FieldComm Group, WirelessHART Brochure
6. FieldComm Group, Intrinsically Secure WirelessHART® Field Device Networks and the Industrial Internet of Things (IIoT)
7. FieldComm Group, HART Specifications. <https://www.fieldcommgroup.org/hart-specifications>
8. FieldComm Group, HART Device Testing Tools User Guide (FCG-PS20066)