CPS Networks

Introduction

- Wireless HART Protocol
- CAN Protocol
- Automotive Ethernet Protocol

Wireless HART

- Wireless HART (Highway Addressable Remote Transducer) is a wireless communication protocol designed for industrial automation and control systems.
- It is an extension of the HART protocol (a widely used wired communication protocol in industrial applications) that operates over wireless networks.

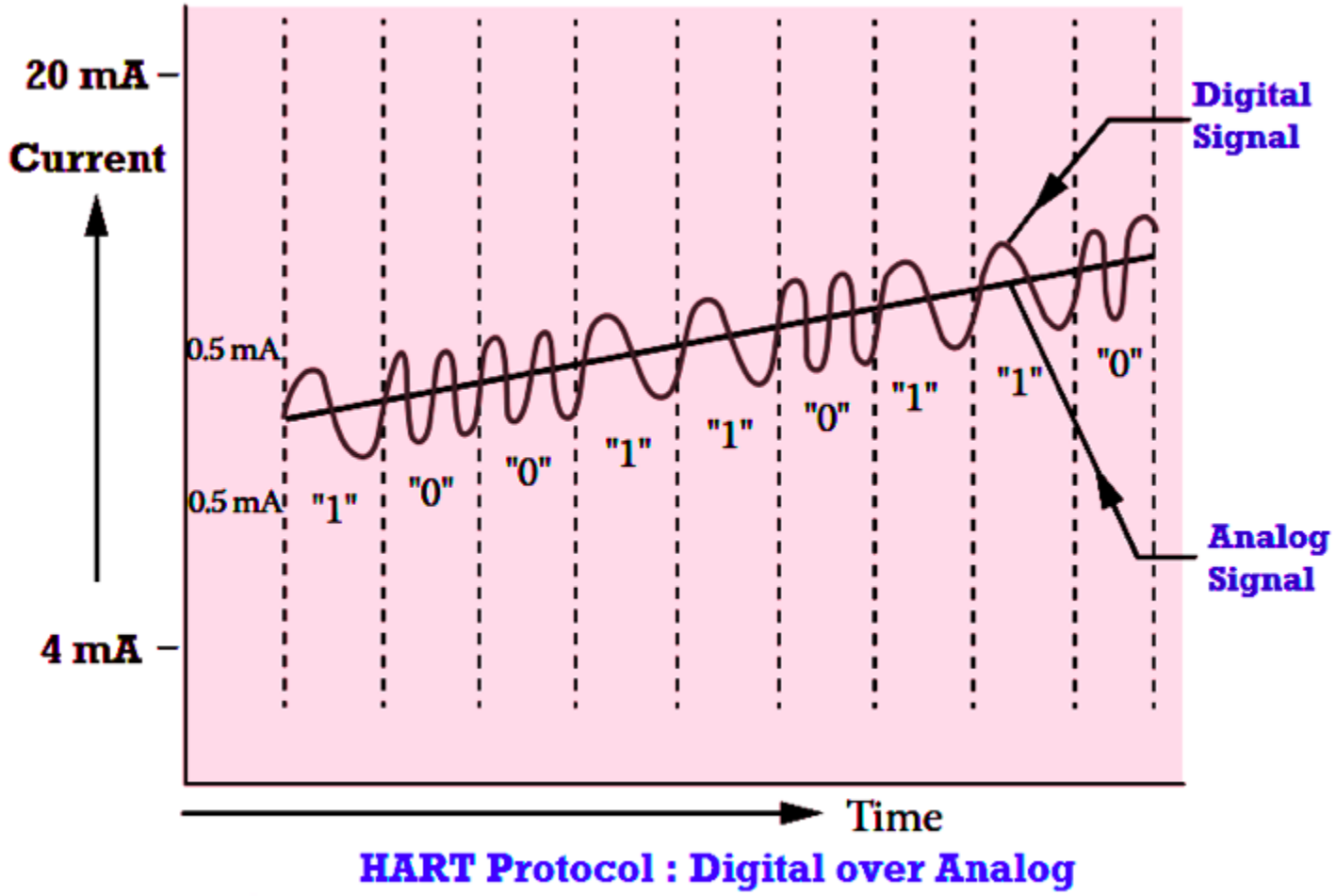
HART (Highway Addressable Remote Transducer)

- Used widely in industrial automation and control
- It is widely used in process industries for communicating with smart field devices like sensors, actuators, and transmitters.
- It is wired communication where digital data is transferred over analog wiring

Overview of HART

- Hybrid Analog-Digital Communication: The HART protocol enables simultaneous transmission of analog and digital signals over the same wiring.
- The analog signal typically represents the process variable (e.g., pressure, temperature) in the form of a 4-20 mA current loop.
- On top of this analog signal, a digital signal is superimposed, allowing bidirectional communication without interfering with the analog signal.

Digital over Analog Signals



Analog and Digital Hybrid

- The analog 4-20 mA signal is used for real-time process control, while the digital signal carries additional device information, such as diagnostics, calibration data, and configuration parameters.
- The digital signal is transmitted using Frequency Shift Keying (FSK) technology, which imposes a low-level AC signal on top of the analog current loop.

Master Slave Communication

- HART operates using a master-slave model.
- The master is typically a control system (like a PLC or DCS), and the slave is the field device (sensor, actuator).
- Up to two masters can be present in a HART network: one primary master (usually a control system) and one secondary master (often a handheld configuration tool or PC-based software).

Compatible with existing Infrastructure

Since HART can transmit data over standard 4-20 mA wiring, it provides backward compatibility with older analog-only devices, making it easier to integrate into existing systems.

The HART protocol can transmit a variety of information, including:

- Device status and health
- Diagnostics and alerts
- Configuration settings
- Calibration and maintenance data
- Multiple process variables (in devices that support multivariable measurement)

HART Command Set

- HART defines a set of commands for communication with field devices.
- There are three types of commands:

1. Universal Commands: Supported by all HART devices (e.g., read process variable, read device status).
2. Common Practice Commands: Commonly supported commands used for calibration, diagnostics, and configuration (e.g., set range, reset device).
3. Device-Specific Commands: Unique to each device, these commands allow access to specialized functions of the device.

Polling Mode

- HART supports **point-to-point** (one-to-one) and **multidrop** (one-to-many) communication.
- In point-to-point mode, the 4-20 mA signal is used for continuous communication with a single device.
- In multidrop mode, multiple devices can share the same communication link, with digital data used for identification and control, but the analog signal is fixed at 4 mA.

Components of HART System

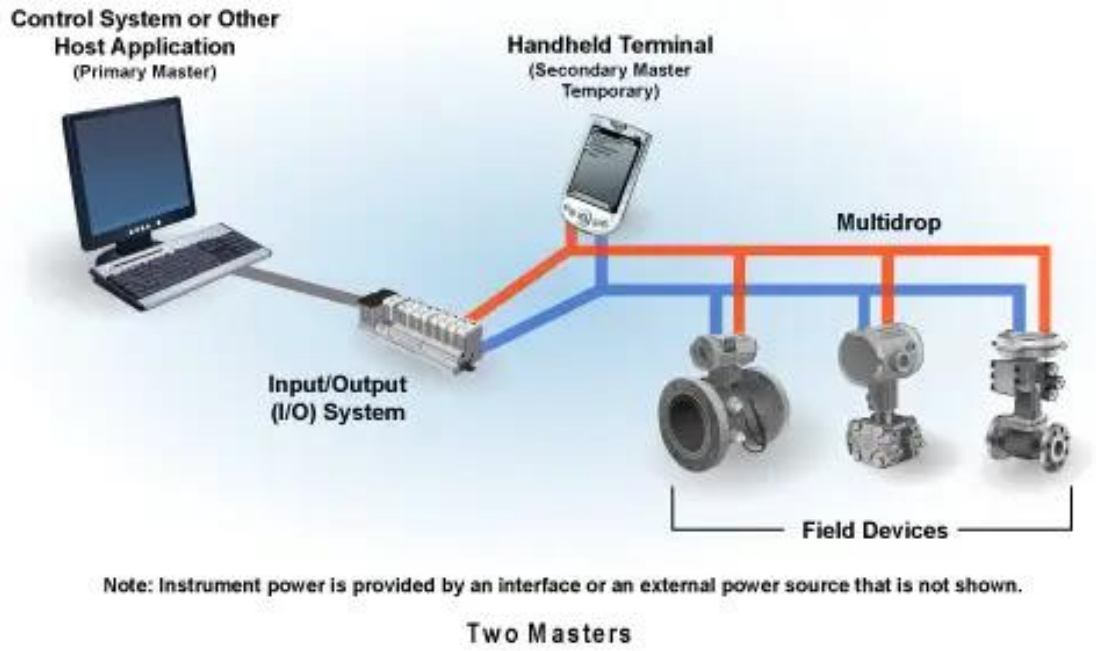
1. Field Devices: These are the sensors, transmitters, and actuators in the industrial environment that send process data or receive control commands.
2. Master Devices:

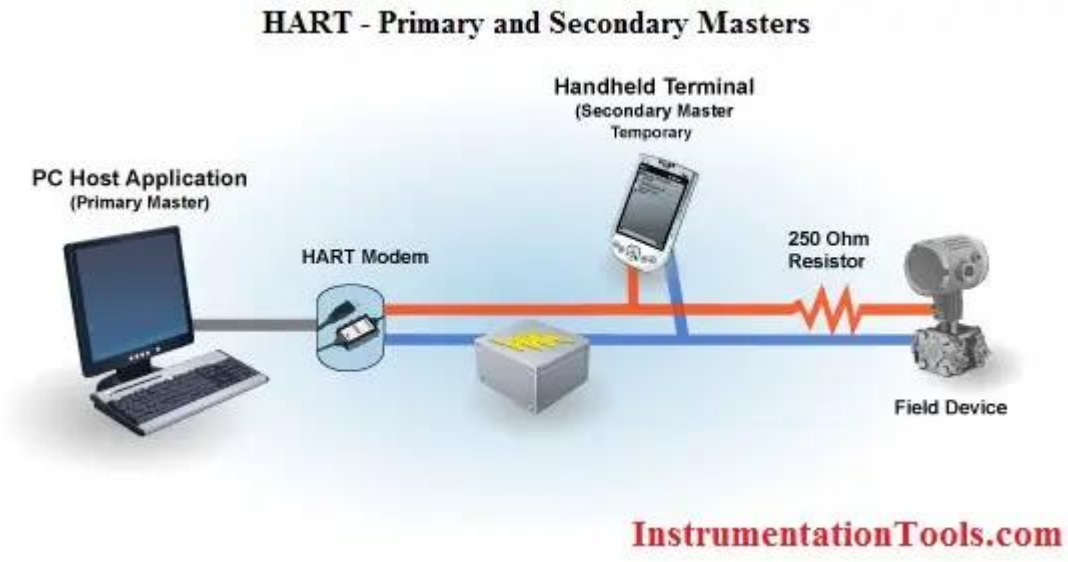
- Primary Master: The main control system, such as a PLC (Programmable Logic Controller) or DCS (Distributed Control System), that operates continuously.
- Secondary Master: A handheld device or software application used for configuring or monitoring devices on the HART network.

3. Network: HART communication takes place over standard 4-20 mA wiring, making use of either point-to-point or multidrop configurations.

Communication Modes

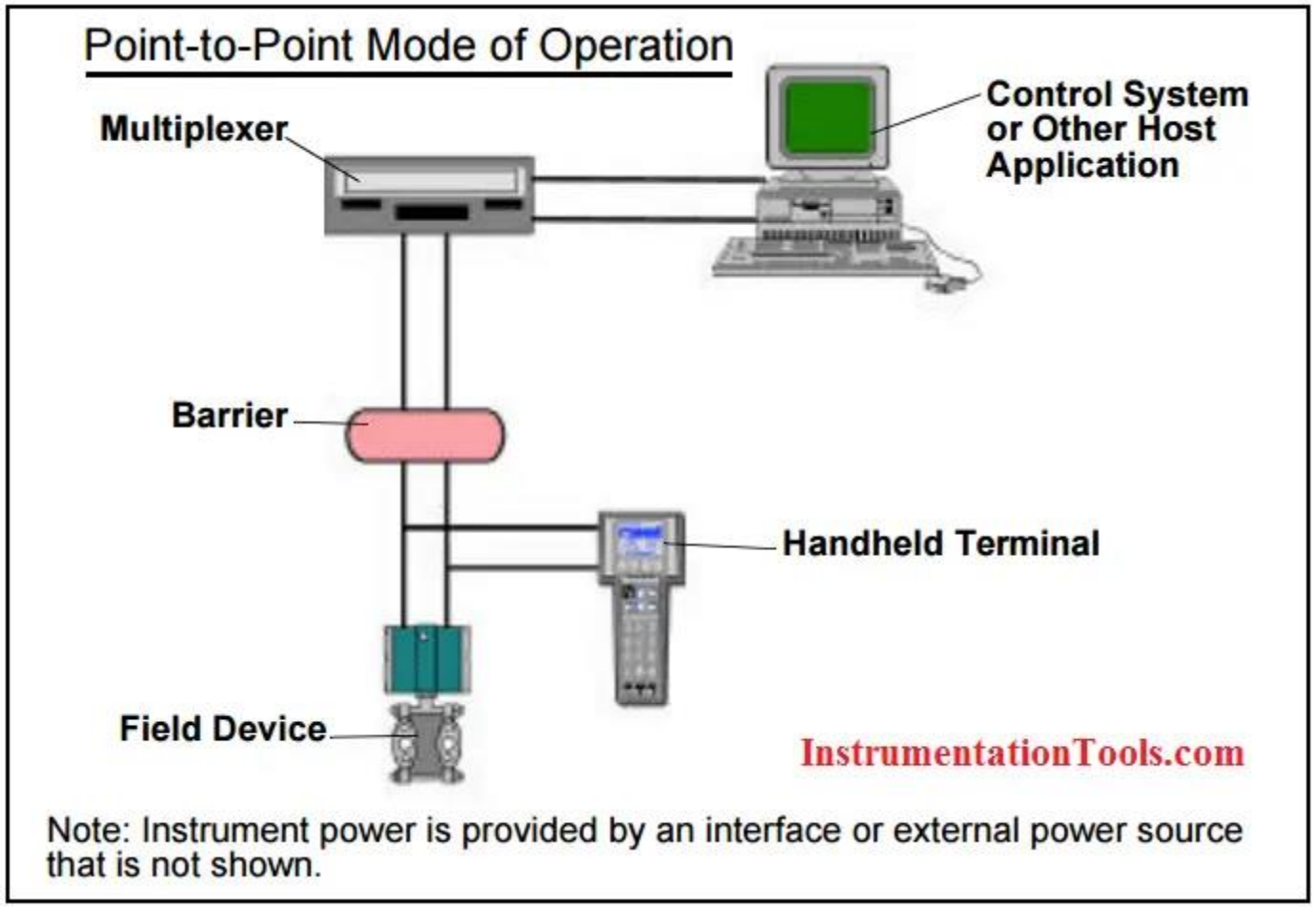
- Point to point mode
- Multidrop Mode





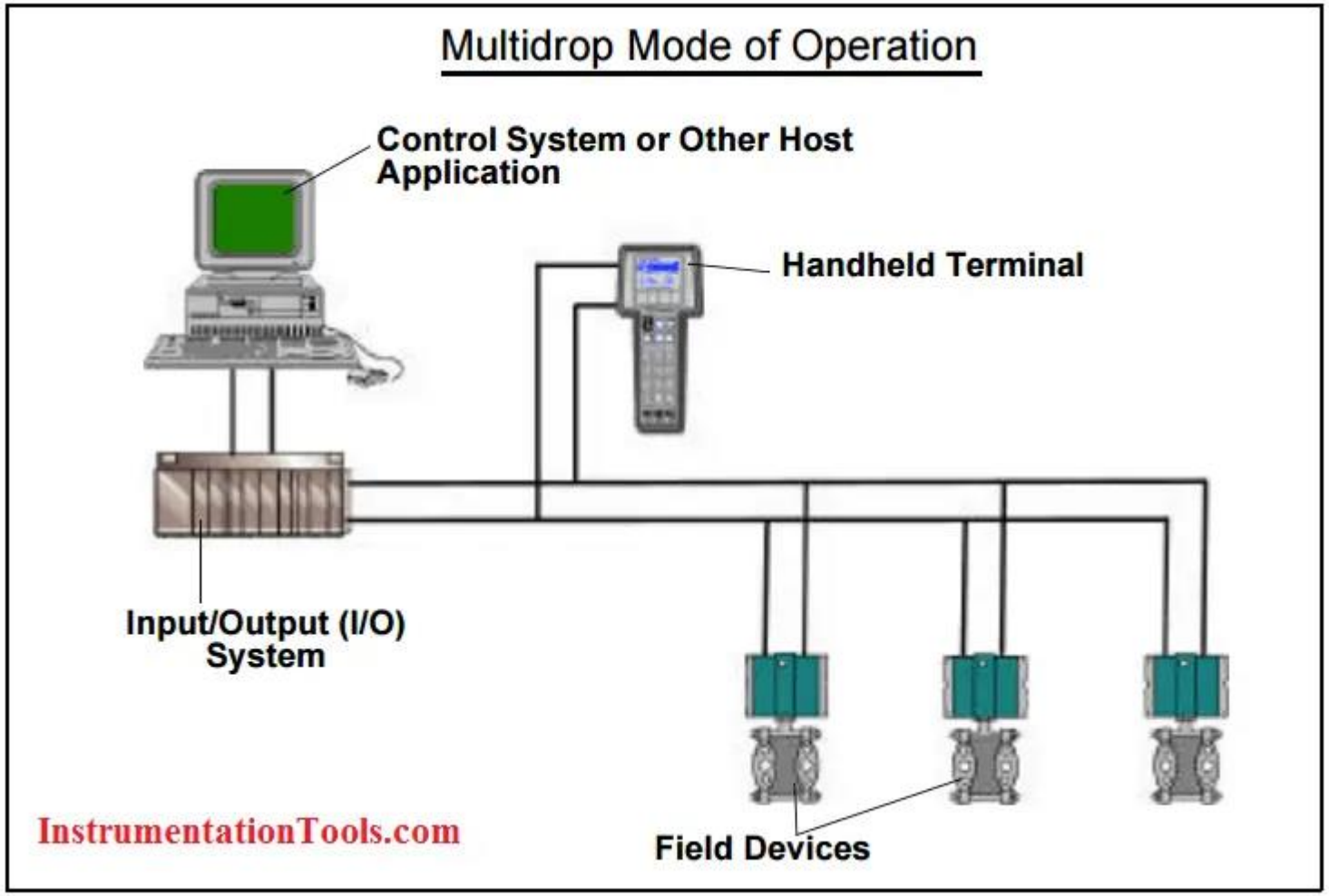
Point to Point Mode

- In this mode, the HART-enabled device is connected directly to the control system via the 4-20 mA loop.
- The analog signal is used for real-time control, while the digital signal is overlaid to send/receive diagnostics or configuration data.



Multidrop Mode

- In multidrop mode, multiple devices are connected to the same wiring.
- The analog signal is fixed at 4 mA, and all communication takes place digitally.
- Each device is assigned a unique polling address, enabling the master to communicate with each device in sequence.



Applications of HART

HART is used extensively in process industries, including:

- **Oil and Gas:** For monitoring pressure, temperature, and flow rates in pipelines.
- **Chemicals:** For controlling batch processes and ensuring the safe operation of equipment.
- **Water Treatment:** For monitoring fluid levels, flow rates, and water quality.
- **Power Generation:** For monitoring turbine parameters and steam pressure.

Advantages of HART

- Compatibility with Existing Systems: Since HART works over existing 4-20 mA wiring, it allows a seamless upgrade of analog systems to include digital communication.
- Cost-Effective: No new wiring is needed to implement HART, making it a cost-effective solution for retrofitting legacy systems.
- Rich Data: HART provides access to a wealth of additional information, such as device diagnostics, which can help in predictive maintenance and improve operational efficiency.
- Interoperability: HART is supported by multiple vendors and devices, ensuring a high degree of interoperability in industrial applications.

Limitations of HART

- Slower Communication: HART’s data transmission rate is relatively slow (1200 bits per second) compared to modern digital fieldbus protocols. This limits its use in real-time control applications.
- Limited Data Transfer: While HART can send additional data, the bandwidth is limited, so it is not suitable for applications that require rapid or large amounts of data transfer.
- Analog Dependency: The hybrid analog-digital nature of HART means that full digital control isn’t possible, and real-time data still relies on the analog signal.

Wireless HART

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Features of Wireless HART

- Wireless Communication
- Mesh Network Topology
- Interoperability
- Security
- Scalability
- Time Synchronization
- Energy Efficiency

1. Wireless Communication:

WirelessHART operates in the 2.4 GHz ISM band (Industrial, Scientific, and Medical band), using Time Division Multiple Access (TDMA) for secure and reliable communication. It leverages a mesh network topology where each device can communicate with multiple other devices, allowing data to hop across multiple nodes to reach its destination.

2. Mesh Network Topology:

In WirelessHART, devices act as both sensors and relays, forming a self-healing mesh network. If one communication path fails, the network automatically reroutes data through other available nodes, enhancing reliability and robustness.

3. Interoperability:

Since WirelessHART is based on the HART standard, it provides backward compatibility with existing HART devices. This makes it easier for industries to integrate WirelessHART solutions with their existing infrastructure.

4. Security:

Security is a critical aspect of WirelessHART. It incorporates encryption (128-bit AES), authentication, and other security mechanisms to ensure that only authorized devices communicate within the network. This helps protect data integrity and confidentiality.

5. Scalability:

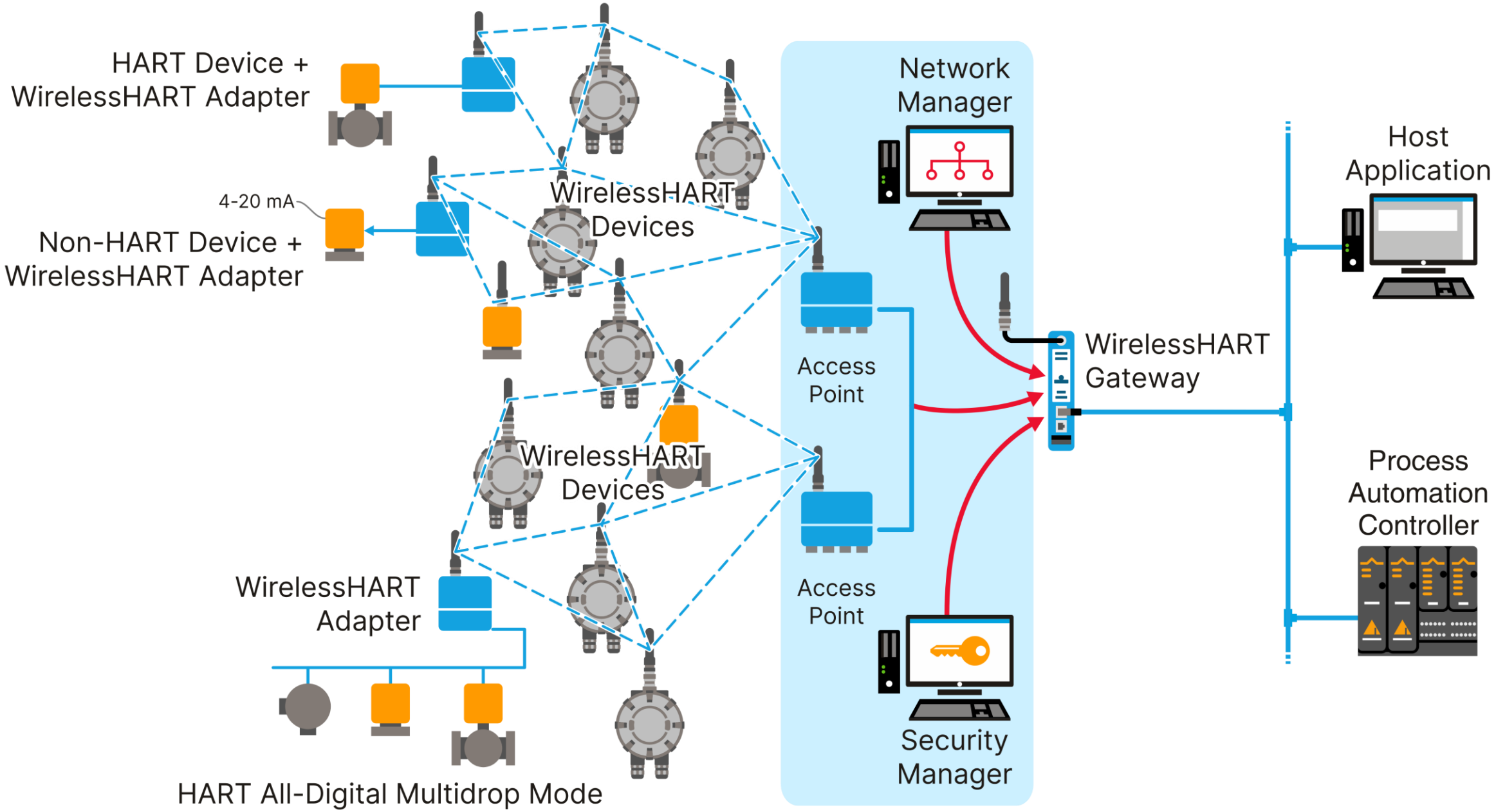
WirelessHART networks can be scaled to accommodate a large number of devices, from a few to thousands. The protocol supports both small and large-scale industrial environments.

6. Time Synchronization:

WirelessHART uses time-synchronized communication to ensure that data is transmitted efficiently without collisions. Each device in the network is synchronized to the central network manager, reducing energy consumption and maximizing battery life.

7. Energy Efficiency:

Devices are designed to be energy-efficient, making WirelessHART ideal for battery-powered sensors in remote or hazardous locations. The TDMA communication scheme allows devices to sleep between scheduled communication intervals.


HART Device +
WirelessHART Adapter
4-20 mA
Non-HART Device +
WirelessHART Adapter
WirelessHART
Devices
WirelessHART
Devices
WirelessHART
Adapter
HART All-Digital Multidrop Mode
Network
Manager
Access
Point
Access
Point
Security
Manager
WirelessHART
Gateway
Host
Application
Process
Automation
Controller

Components of Wireless HART

1. Field Devices:

- These are the wireless sensors and actuators deployed in the industrial environment. They collect data and perform control actions, acting as nodes in the mesh network.

2. Gateway:

- The gateway acts as a bridge between the WirelessHART network and the plant automation system (often a Distributed Control System or DCS). It converts the wireless data to standard wired protocols and forwards it to the control systems.

3. Network Manager:

- The network manager is responsible for configuring and managing the wireless network, including routing, scheduling, and ensuring network security. It dynamically adjusts routes and communication times to optimize performance.

4. Host System:

- This is the central control or monitoring system (like a DCS or SCADA system) that interacts with the WirelessHART network, providing a user interface for managing devices and accessing data.

Applications

- Oil and Gas: For remote monitoring of pipelines, pumps, and equipment in hazardous environments.
- Chemical and Petrochemical: For monitoring chemical processes and ensuring safety in chemical plants.
- Power Generation: In power plants for monitoring temperature, pressure, and other parameters.
- Manufacturing: To monitor equipment performance and ensure efficient production processes.

Advantages

- Reduced Cabling Costs: Since it is wireless, installation costs are significantly lower compared to wired networks.
- Flexibility: It is easy to add, move, or replace sensors without extensive rewiring.
- Reliability: The mesh network ensures communication reliability, even in harsh industrial environments.
- Long Range: The mesh topology allows communication over longer distances by hopping through intermediate devices.

Limitations

- Limited Bandwidth: The wireless nature of the network means it has less bandwidth compared to wired systems, making it less suitable for high-speed data or real-time control of fast processes.

- Interference: Operating in the 2.4 GHz band can sometimes lead to interference from other wireless devices like Wi-Fi.

- Battery Life: Battery-powered devices need periodic maintenance to replace batteries, although this can be mitigated by the low-power design of WirelessHART devices.