HART Device Networks

Chapters 7 and 8 in the Textbook

Professor: HONGWEI ZHANG
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Presented By: ABDUL AZIZ REEHAN SHAIK (fq8875)
fq8875@wayne.edu

OUTLINE

- Introduction
- HART Device Networks In Detail
- HART Architecture
- HART Communication Modes
- HART Network Topologies
- HART Commands
- HART Communication Stack
- System Tools
- WirelessHART Tools
- Installation
- Application & Future Trends

Introduction

What is HART?

HART-Highway Addressable Remote Transducer

- HART is a digital industrial Automation Protocol or Communication Protocol.
- A HART device is a microprocessor-based process transmitter which supports a two-way communication with the Host.
- HART digital signal is modulated onto the 4-20 mA analog signal at a higher frequency and is observed by the process control equipment.

Introduction (Contd..)

What is a 4-20 mA Analog Signal?

- The analog 4-20 mA is a current loop which is used for analog signaling.

- With 4 mA being the lowest range and 20 mA being the highest range.

Why is the current loop used?

- Because the accuracy of the signal is not affected by voltage drop in the connection wiring.

- And also the loop supplies the operating power to the devices.

HART Protocol

HART Protocol uses Two types of modes:

- Point-To-Point and Multidrop modes.

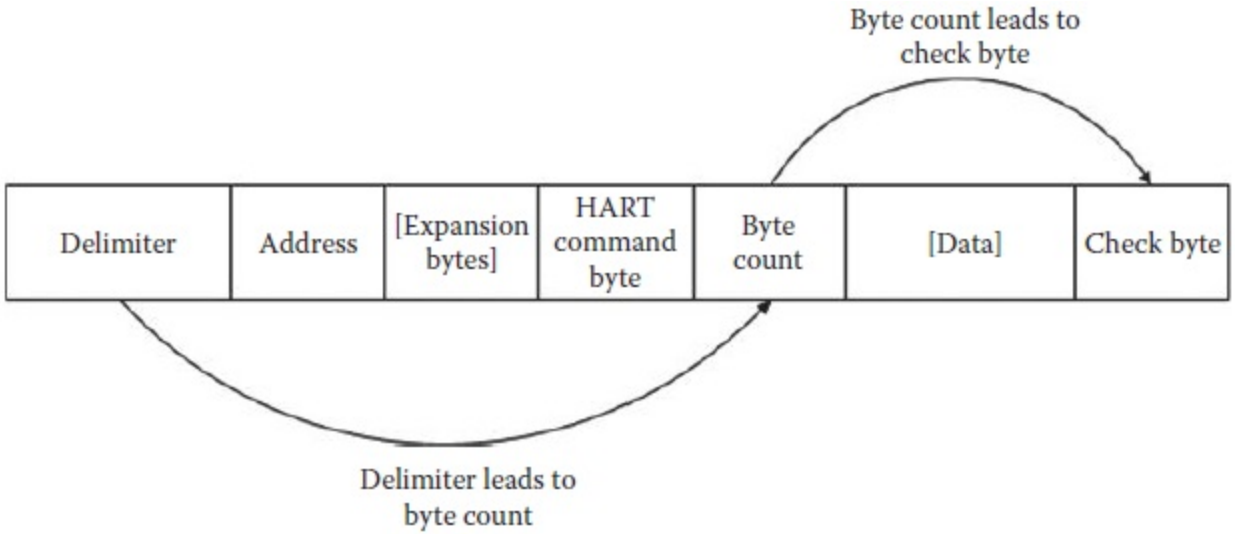
- In Point-to-Point or also known as Analog/Digital mode the HART protocol uses only one instrument.

- In Multidrop mode more than one instruments can be on the instrument cable signal pair.

In detail discussion in Network Topologies.

Packet Structure of HART

Field Name	Length (in bytes)	Purpose
Preamble	5–20	Synchronization and Carrier Detect
Start byte	1	Specifies Master Number
Address	1-5	Specifies slave, Specifies Master and Indicates Burst Mode
Expansion	0-3	This field is 0–3 bytes long and its length is indicated in the Delimiter
Command	1	Numerical Value for the command to be executed
Number of data bytes	1	Indicates the size of the Data Field
Data	0–255	Data associated with the command. BACK and ACK must contain at least two data bytes.
Checksum	1	XOR of all bytes from Start Byte to Last Byte of Data



How Does HART Work?

- HART enables a 2-way field communication to and from the smart field devices.
- HART Protocol communicates at 1200bps without interrupting the 4-20mA signal and allows a Host (Master) to get more than two updates from the smart field devices(Slaves).
- HART is a Master/Slave protocol. The Slave responds only when the Master requests.
- HART Communication occurs only between two HART-enabled devices.
- Provides two simultaneous channels, 4-20mA analog signal and the digital signal.

How Does HART Work?(Contd..)

- The Primary Value(PV) is communicated through the 4-20mA analog signal current loop.
- Any kind of additional data is communicated through the digital signal.
- Digital signal contains information such as Device Status, Diagnostics, Additional measured or calculated values.

HART Field Devices

All HART field devices must have the following properties:

- Adherence to Physical and Data Link Layer requirements, i.e., they must follow all the rules of the physical and data link layer.
- Support for minimum Application Layer requirements.
- Support for all Universal Commands.(In detail in HART Commands)
- The 4-20mA current loop connects the HART field devices to the Control System.
- Current loop always connected to PV, in case the devices support more than one loop then the second loop is connected to Secondary Variable(SV).

In detail about all the layers in Communication Stack section.

HART Networks

All Communication Systems can be characterized by the Throughput and Latency.

- Throughput: Indicates the maximum number of transactions per second that can be communicated by the system.
- Latency: Measures the worst-case maximum time between the start and completion of a transaction.

HART can provide up to 2.65 PV updates per second.

If the network becomes unsynchronized then the throughput can reduce to 0.88 PV updates per second.

In multidrop latency increases due to many no.of commands in line.

HART Performance Summary

TABLE 7.1 Summary of Latency for I/O Systems

	Measured in Seconds			
Number of Channels	Point-to-Point	Point-to-Point (Unbuffered)	Multidrop	Multiplexed
1	0.38	1.14	0.38	0.38
4	0.38	1.14	1.51	2.73
8	0.38	1.14	3.02	5.46
16	0.38	1.14	6.04	10.92
32	0.38	1.14	12.08	21.84

TABLE 7.2 Summary of Throughput for I/O Systems

	Measured in Transactions per Second			
Number of Channels	Point-to-Point	Point-to-Point (Unbuffered)	Multidrop	Multiplexed
1	2.65	1.14	2.65	1.47
4	10.60	4.56	2.65	1.47
8	21.19	9.12	2.65	1.47
16	42.38	18.24	2.65	1.47
32	84.77	36.48	2.65	1.47

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HART Device Networks In Detail

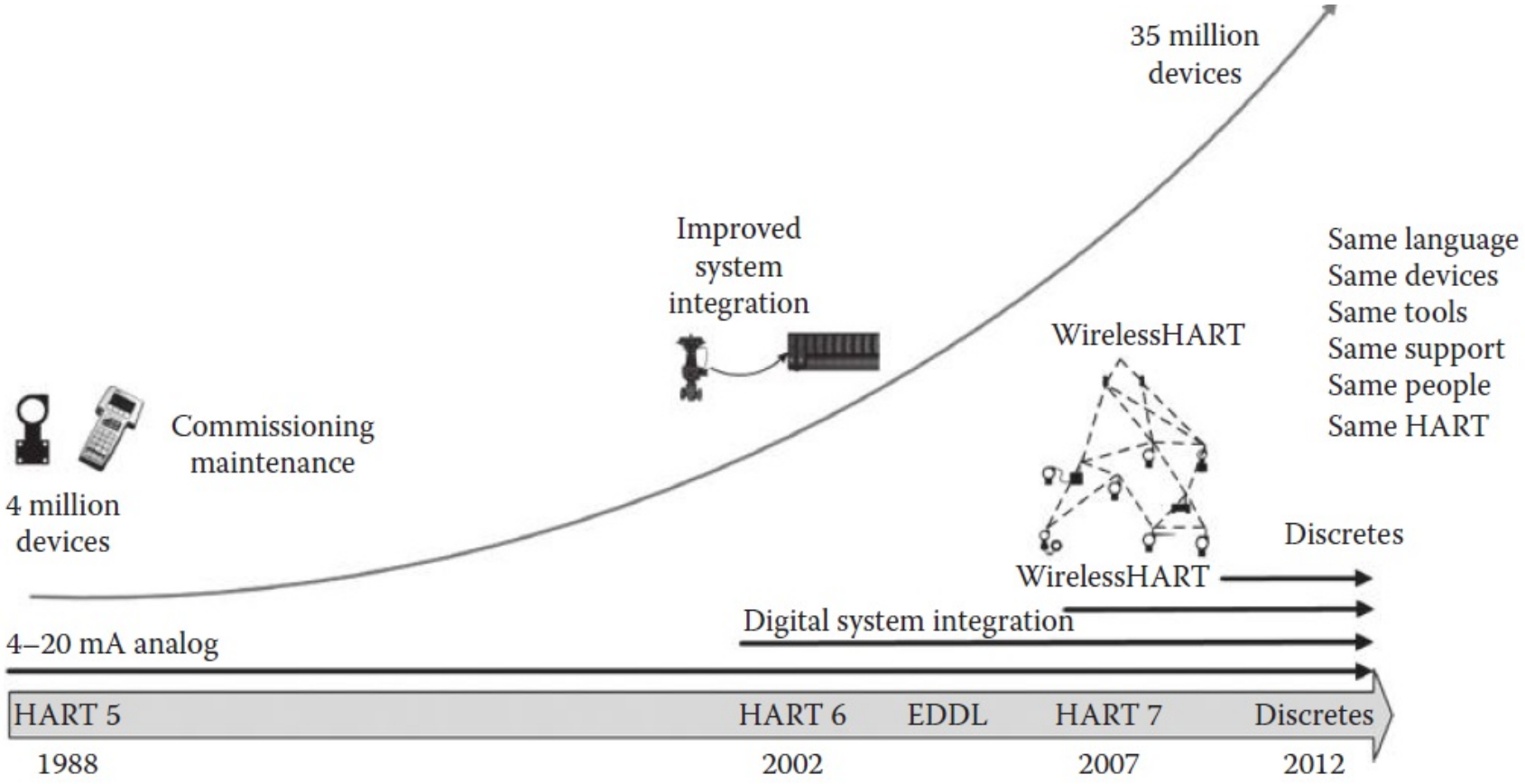
- Applications utilizing the HART devices are traditional monitoring and process control, safety applications, asset management, equipment health monitoring applications.

- In these applications the measurements include the following, temperature, pressure, flow, pH, conductivity, discretes, level, vibration, mass flow, energy, valve position.

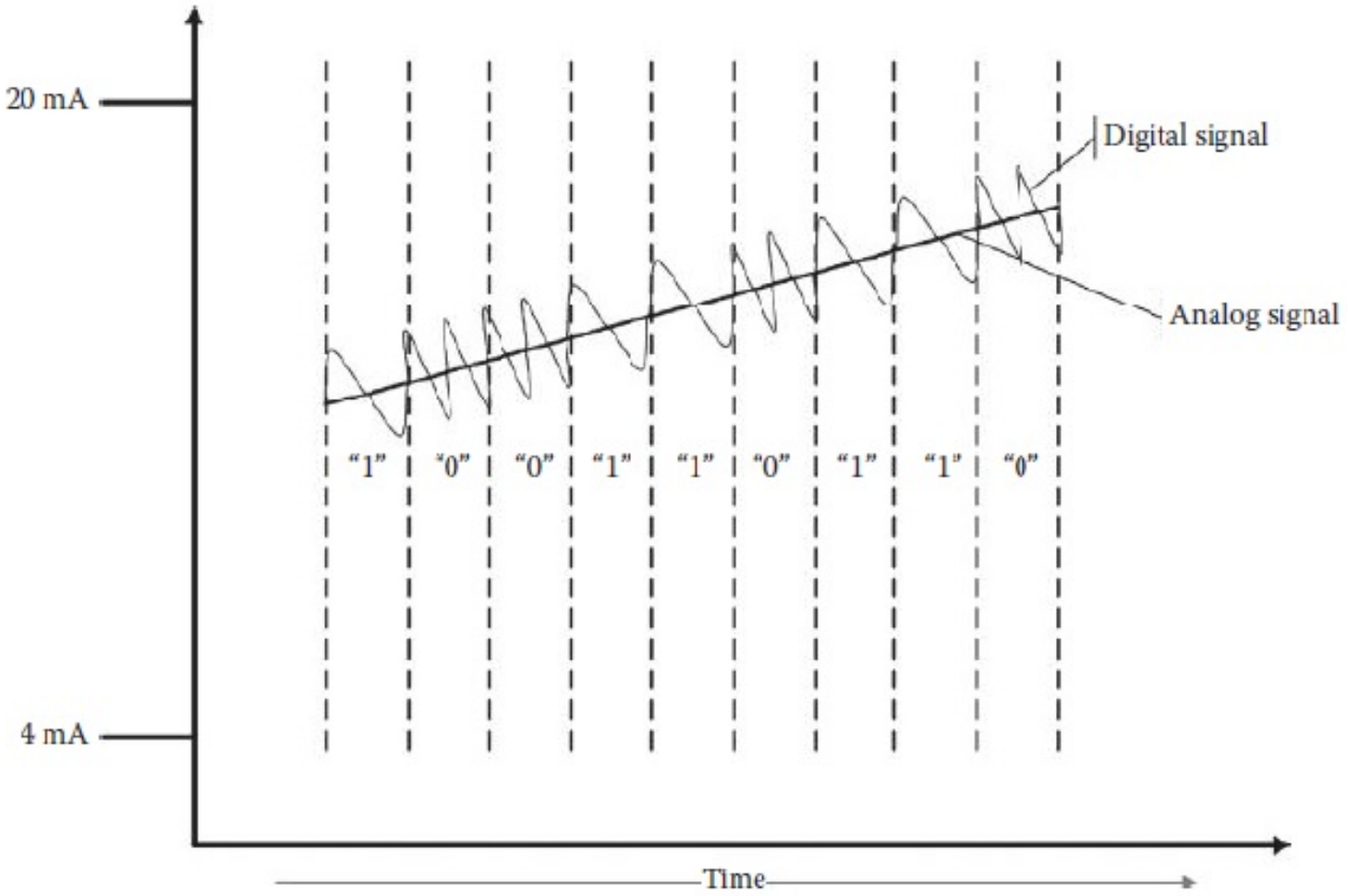
- The earliest HART Communications protocol was based on the BELL 202 Telephone Communication Standard and was operated using the Frequency Shift Key(FSK) principle.

- The digital signal is made up of two frequencies: 1200 and 2200 Hz representing the 1 and 0 bits respectively.

Evolution of HART



Wired HART Simultaneous Analog and Digital Communication



Reduced Configuration, Installation and Checkout

•HART devices are designed to work for a wide range of applications.

•The devices have to be configured. Each device is given a tag, and a set of signal conditioning parameters.

•The DDL(Device Description Language) checks whether the device supports the particular parameters.

•To configure the control system we need different set of information such as the measurements supported by the device and Signal information associated with the measurements.

•Control System Configuration must be downloaded into the control system at different levels of development.

•HART provides many sets of features which support overall configuration, installation and checkout procedures.

Monitoring, Control and Safety

TABLE 8.1 Usage Classes

Safety	Class 0: Emergency action	Always critical
Control	Class 1: Closed-loop regulatory control	Often critical
	Class 2: Closed-loop supervisory control	Usually noncritical
	Class 3: Open-loop control	Human in the loop
Monitoring	Class 4: Alerting	Short-term operational consequence (e.g., event-based maintenance)
	Class 5: Logging and downloading/uploading	No immediate operational consequence (e.g., history collection, sequence-of-events, preventive maintenance)

Importance of message timeliness increases

Reference ISA100.11a annex C [5].

- 6 different classes of sensor and control.
- Measurements are used by operators to monitor things in the plant.
- Used to generate reports and make decisions of the process, maintenance activities and schedule production runs.

WirelessHART

- Wired networks such as Foundation Fieldbus, Profibus, HART are all well established and continue to dominate in the industry.
- WirelessHART includes a combination of device improvements, network technology and network management.
- Network management is key to operation of wireless network. Used to manage the network resources efficiently, schedule communications to meet the application requirements, establish routing to meet reliability and performance goals.
- Security, reliability, ease of use and battery life are some of the things taken care by the network manager.
- WirelessHART devices can be line powered or Non-line powered(eg. batteries).
- Batteries are more efficient and flexible because of the on-off ratio.

Security

- HART evolves continuously. Current release 7 HART introduced the WirelessHART as its first wireless mesh network.
- Biggest Challenge addressed by wirelessHART is the plant security.
- WirelessHART employs robust security measures to protect the network and secure the data at all times.
- It uses the industry standard 128-bit AES Encryption algorithm at multiple levels.
- Data link layer holds a secret key to authenticate each data transmission.
- At the Network layer each session has a different key to encrypt peer-to-peer communication.

Security (Contd..)

- Different Join Key is used for each device to encrypt and authenticate during the device join process.
- The Network Manager periodically keeps changing the keys.
- WirelessHART also supports the Access Control List through the quarantine state as part of the joining process.

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HART Architecture

- HART device is a communications protocol.
- Digital Data exchange between the field device and the Host computer.
- Host is often the Master device or the Gateway in case of wirelessHART.
- HART Host first has to talk to find out what the device provides.
- How does HART identify the device? How HART describes the device capabilities? What data is exchanged?

Device Identification

- Each HART device has a 38-bit address consisting of manufacturer ID, device type code, and a device unique identifier.

- The master must know the address of a field device in order to communicate successfully.

How does the Master connect to Slave device?

- Command 0, Read unique Identifier—Enables the master to learn the address of the slave device without user interaction.
- Command 11, Read Unique Identifier by Tag– Useful if no more than 15 devices in the network.

Electronic Device Description Language(EDDL)

- Is a machine readable language used to describe the devices in a common and consistent way.
- Describes the device, methods provided by device, measurement and device parameters supported, configuration information.
- A DD file provides a picture of all the parameters and functions of a device in a standard language.
- HART DDL is used to write the DD. Resembles C Language.

EDDL (Contd..)

```
VARIABLE low_flow_cutoff
        {
        LABEL [low_flow_cutoff];
        TYPE FLOAT;
                {
                DISPLAY_FORMAT "6.4f",
                }
        }
MENU configure_io
        {
        LABEL [configure_io]
        ITEMS
                {
                FLOW_UNITS,             /* VARIABLE         */
                rerange                 /* edit-display     */
                operate_mode,           /* variable         */
                flow_config             /* menu             */
                }
        }
```

Accessing Data

- The most common data types are Process Variable/Primary Variable (PV), a percentage of range, and a digital reflection of analog mA signal or the device status.

- These values are mapped to the HART protocol PV, Secondary Variable(SV), Tertiary Variable(TV), Fourth Variable (FV).

Example: Mass flow meter has the derived values obtained.

- PV – mass flow value.
- SV – Static Pressure.
- TV – Temperature.
- FV – Digital mA signal reflection.

These mappings are user selectable.

Wiring Parameters and Commanding Devices

- HART also describes how to write data back to the instrument.
- HART also supports the commands for calibrating the instruments based on the application requirements.
- For Wired Devices all the communications are carried out over 4-20 mA current loop wiring.
- For WirelessHART devices the communication is carried out over–the--air through IEEE 802.15.4 radios.

Design Approach

- The HCF (HART Communications Foundation) provides HART specifications that can be used by suppliers to design and build devices, tools, and applications.

Several Design Approaches are:

- The device description DD.
- HART messages.
- Service or Protocol Structure.
- HART Commands which are the content of HART messages.

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- WirelessHART Tools
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HART Communications Mode

- HART protocol is Master/Slave based communications protocol.
- Slave communication is initiated only when the Master requests.
- Two Masters can connect to each HART loop.
- Primary Master can be the Distributed Control System, Programmable Logic Controller (PLC) or any Personal Computer.
- Secondary Master is generally a Handheld Terminal or another PC.
- Slave Devices consist of Transmitters, Actuators, and controllers which respond to commands from Master.
- Types of communications are Request/Response, Burst Mode, Events and Event Notifications, Block Data Transfer.

Request/Response

- HART Communications protocol uses Request/Response messages to access and change parameter values, invoke device methods, configure devices and in wirelessHART manage the network devices.

TABLE 8.2 Command 1 Read Primary Variable Request

Byte	Format	Description
None		

TABLE 8.3 Command 1 Read Primary Variable Response

Byte	Format	Description
0	Enum	Primary variable units
1–4	Float	Primary variable

Burst Mode

- Allows the master to instruct the slave device to continuously broadcast a standard HART reply message.
- Master receives the message in burst mode until it tells the slave to stop bursting.
- WirelessHART devices support Burst mode whereas in Wired it is optional.

TABLE 8.5 HART Burst Modes

Burst Code	Mode	Description
0	Continuous	The *Burst Message* is published continuously at (worst case) the minimum update period
1	Window	The *Burst Message* is triggered when the source value deviates more than the specified trigger value
2	Rising	The *Burst Message* is triggered when source value *Rises Above* the specified trigger value
3	Falling	The *Burst Message* is triggered when the source value *Falls Below* the specified trigger value
4	On-change	The burst message is triggered when any value in the message changes

Events and Event Notification

- Event notification publishes changes in the Device Status.
- It is possible to specify limited set of bits that will trigger event notifications.
- A de-bounce interval is configured.
- Once the event is released, it is transmitted repeatedly until it is acknowledged.
- Event notifications are built upon burst mode operation.
- The two distinct methods to display events are: Device Status and Common Practice Command 48.

Events and Event Notification(Contd..)

- List of Commands used to setup and manage event notifications:

Command 115 is used to determine the configuration of the event notification
Command 116 selects the bits that can trigger an event notification
Command 117 controls the timing of event notifications
Command 118 is used to enable or disable event notification
Command 119 is used to acknowledge the event notification

• The latest set of device status, config change counter and command 48 response bytes are always included in Command 119.

• Command 116 is used to identify the bits that may trigger an event notification.

Block Data Transfer

- Allows the device to transfer blocks of information.
- It is classified as a Transport layer service.
- Establishes connection between host and slave and transfers stream of data.
- Maximizes the utilization of HART Communication.
- Connection for this kind of communication are established by the command 111 to a specific port.
- Command 112 is used to transfer data to and from the field device.

Features of Block Data Transfer

Index	Requirement	Feature
1	Maximize data throughput	The maximum number of bytes to be transferred in a transaction is negotiated when the *Port* is opened. The more data transferred in each transaction, the more efficient the block transfer becomes.
2	Slaves and masters have differing communication buffer space	Data are transferred in blocks as large as both the master and the slave support.
3	Transfer must be reliable. No data may be duplicated or lost.	Byte counters are used to track the data transferred. Acknowledgment indicates which byte count is next expected by the recipient.
4	Must be flexible to support differing application needs	Transfer is based on a virtual connection to a *Port*. Different *Ports* support different, well-defined functions. A block of ports are allocated for device-specific requirements.
5	Transfer must be synchronous	Function codes are used to open, close, or reset a port. The port is not closed until the master and the slave both agree the transfer is complete.

OUTLINE

- Introduction
- HART Device Networks In Detail
- HART Architecture
- HART Communication Modes
- HART Network Topologies
- HART Commands
- HART Communication Stack
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- WirelessHART Tools
- Installation
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HART Network Topologies

Point-to-Point Network

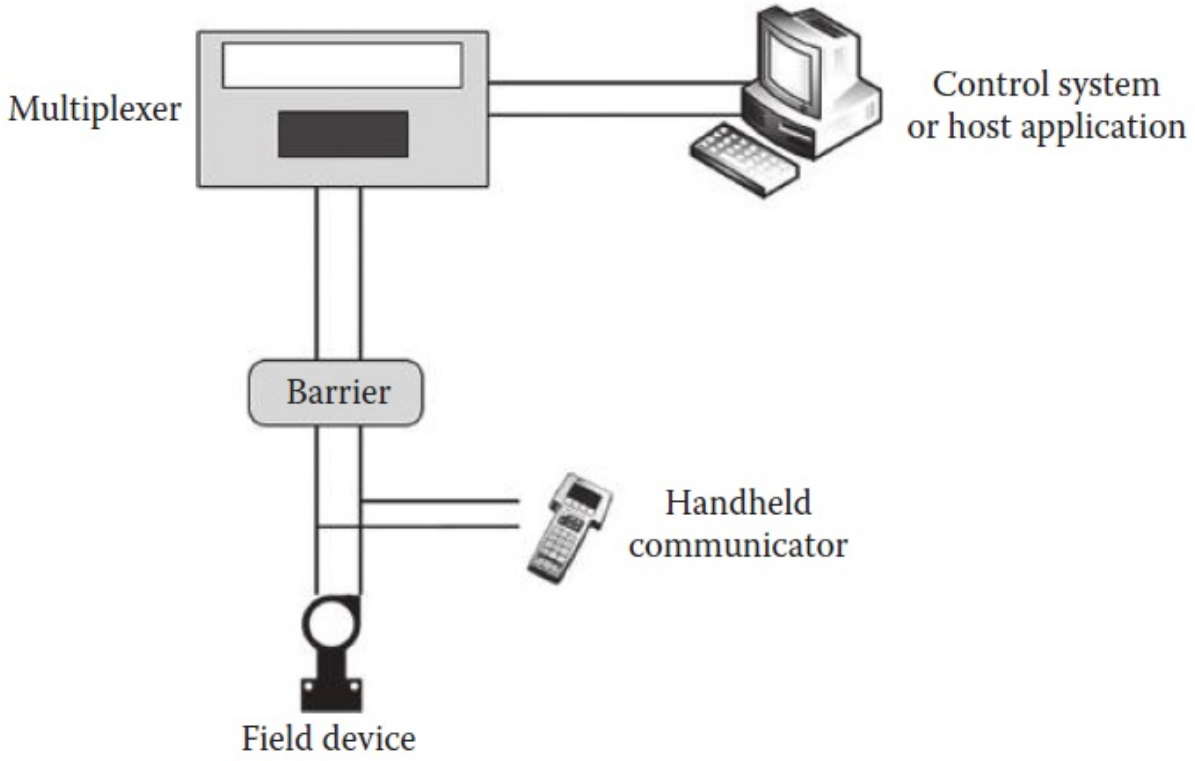
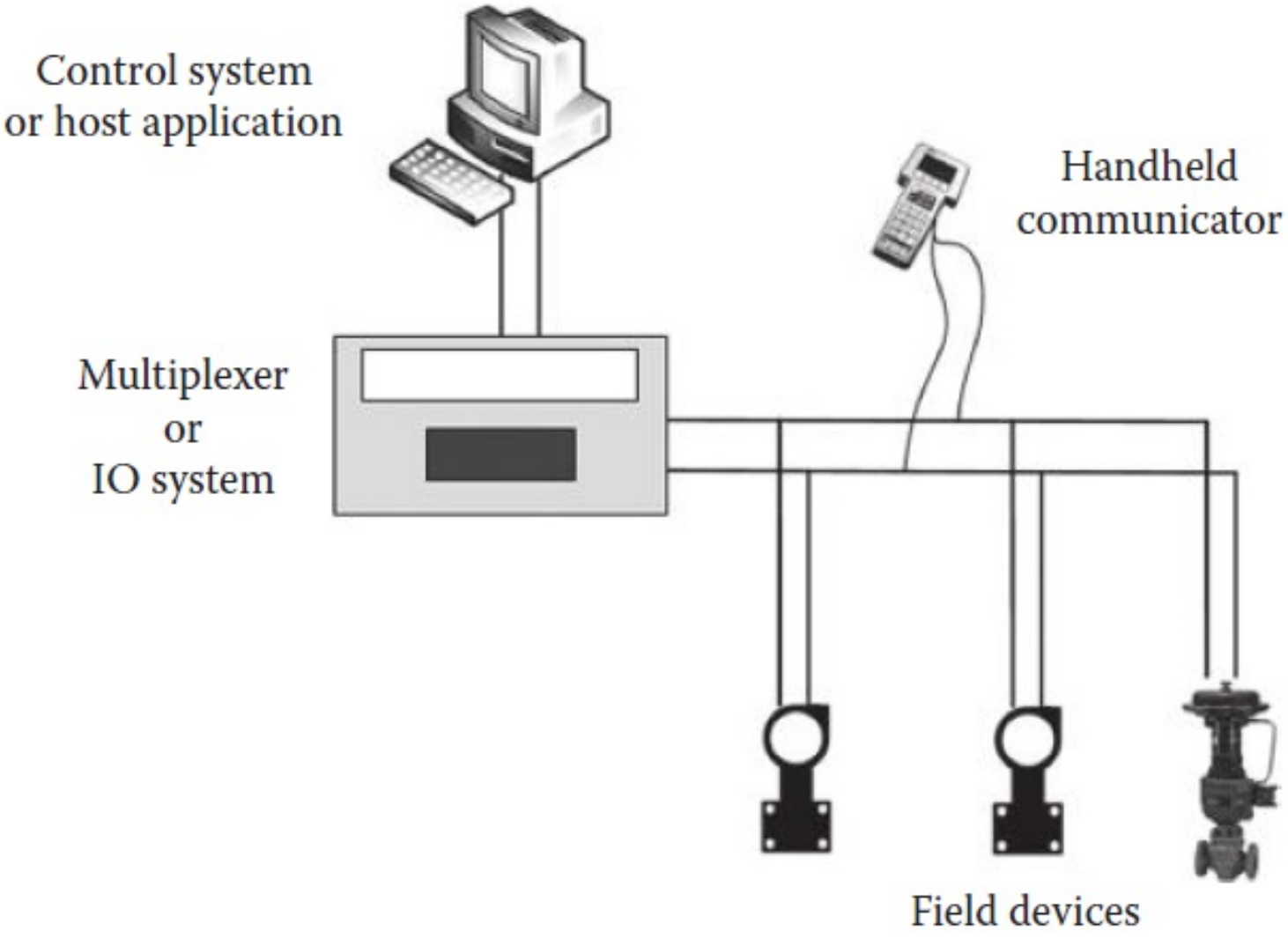


FIGURE 8.6 Point-to-point mode of operation. *Note*: Instrument power is provided by an interface or external power source that is not shown.

Point-to-Point (Contd..)

- It is a traditional 4-20mA analog signal based communication protocol.
- Analog signal transfers Primary variable whereas the digital signal transfers additional device data such as Secondary Variable, operations, maintenance, and diagnostic purposes.
- Point-to-Point is most commonly used topology.
- Most DCS suppliers provide the IO with integrated HART capabilities.
- The 4-20mA device signal is sometimes directly connected to an IO channel.

Multidrop Network

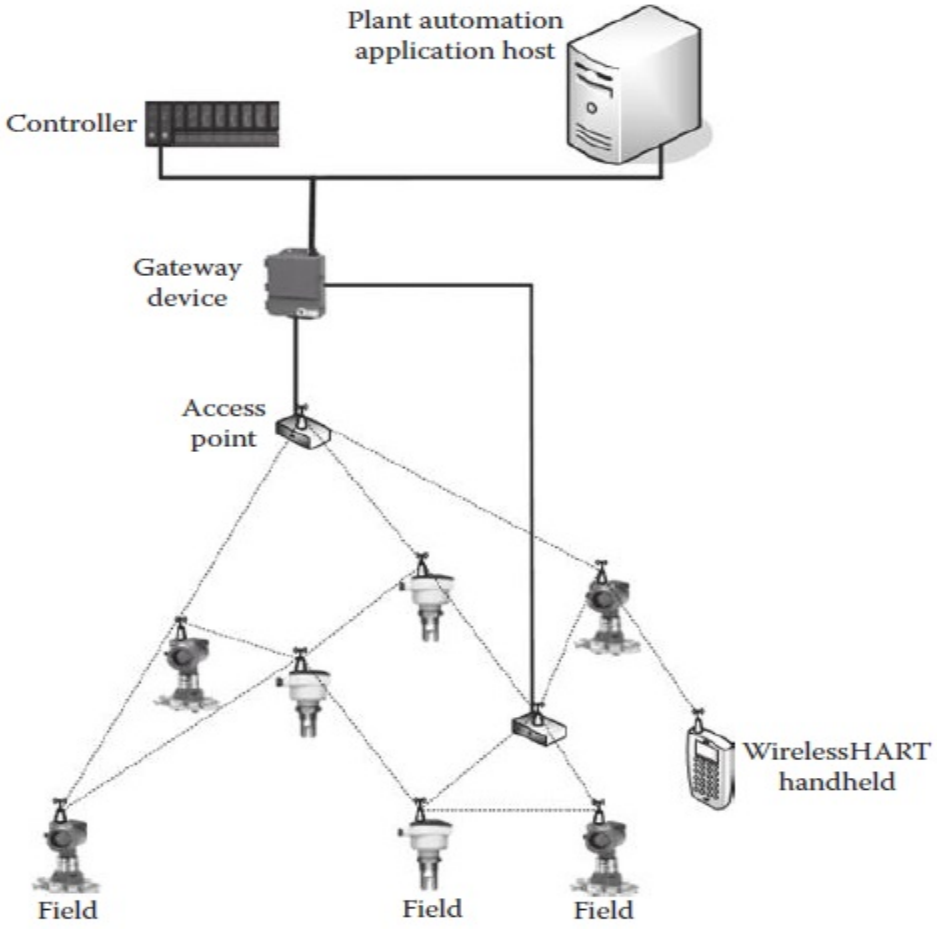


Multidrop Network(Contd..)

- It requires a single pair of wire.
- Only if necessary a power supply for the devices.
- All the process values are transmitted digitally.
- The current flowing through each device is fixed to a minimum which is 4mA.
- In Multidrop networks the throughput remains the same (2-3 tps) but the latency increases as there are a number of commands in line due to increase in number of field devices.

WirelessMesh

- WirelessMesh is the network topology for WirelessHART technology.



WirelessMesh(Contd..)

- WirelessHART builds on the wired HART universal, common practice and device specific commands.
- Since it is similar to HART, installed host applications can use wireless gateway.
- Access wireless-enabled HART field devices and new wireless-only HART field devices.
- WirelessHART is a secure networking topology using the 2.4Ghz ISM radio band.
- WirelessHART utilizes the IEEE 802.15.4-DSSS radios with channel hopping on packet by packet basis.

OUTLINE

- Introduction
- HART Device Networks In Detail
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- HART Communication Stack
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HART Commands

- At the Application Layer HART uses Commands for Data Transfer.

There are Three types of Commands in HART protocol

- Universal Commands
- Common Practice Commands
- Device Specific Commands

- All the devices using HART protocol must recognize and support the Universal Commands. These provide the access to information useful in normal operations.

- Common Practice commands provide functions implemented by many, but not all the HART devices.

- Device Specific Commands are unique to each field device based on the application.

HART Commands(Contd..)

TABLE 8.7 HART Universal, Common Practice, and Device-Specific Commands

Universal	Common Practice	Device Specific
Read manufacturer and device type	Read selection of up to four dynamic variables	Read or write low-flow cut-off
Read primary variable (PV) and units	Write damping time constant	Start, stop, or clear totalizer
Read current output and percent of range	Write device range values	Read or write density calibration factor
Read up to four predefined dynamic variables	Calibrate (set zero, set span)	Choose PV (mass, flow, or density)
Read or write 8-character tag, 16-character descriptor, date	Set fixed output current	Read or write materials or construction information
Read or write 32-character message	Perform self-test	Trim sensor calibration
Read device range values, units, and damping time constant	Perform master reset	PID enable
Read or write final assembly number	Trim PV zero	Write PID setpoint
Write polling address	Write PV unit	Valve characterization
	Trim DAC zero and gain	Valve setpoint
	Write transfer function (square root/ linear)	Travel limits
	Write sensor serial number	User units
	Read or write dynamic variable assignments	Local display information

WirelessHART Commands

- Build on same patterns for device communications.
- Additional commands are for network management, gateway communications and other functionalities by the network manager.

TABLE 8.8 WirelessHART Commands

Gateway	Network Manager	Devices
Writing networking IDs	Joining	Read wireless device capabilities
Writing network tags	Health reports	Reporting health
Managing device list entries	Report	Supporting networking resources
Managing blacklists and white lists	Path, route, and transport failures	Reporting path, route, and transport failures
Caching published data from devices	Timetable management	Supporting timetables
Managing network constraints	CCA mode management	Supporting routes
Managing stale data settings	Network flow control	Supporting superframes
Supporting host applications	Managing superframes	Supporting links
Supporting active advertising	Managing links	Supporting graphs
Maintaining device lists	Managing graphs	Supporting security keys
Flushing cached device information	Writing security keys	Supporting routes
Time source for network	Monitoring and grooming the network	
Managing device scheduling flags	Managing routes	

OUTLINE

- Introduction
- HART Device Networks In Detail
- HART Architecture
- HART Communication Modes
- HART Network Topologies
- HART Commands
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- WirelessHART Tools
- Installation
- Application & Future Trends

HART Communication Stack

- The HART Protocol has extensively evolved from the initial 4-20mA analog signal to the currently used wired and wireless-based technology with many new features such as Security, Block data transfer, event notifications, and advanced diagnostics for a few to name.

- Wired Protocol includes 4 layers from the OSI model namely Physical, Data Link, Transport and Application layers.

- Whereas the Wireless Protocol includes one additional Layer which is the Network Layer.

HART Communication Layers

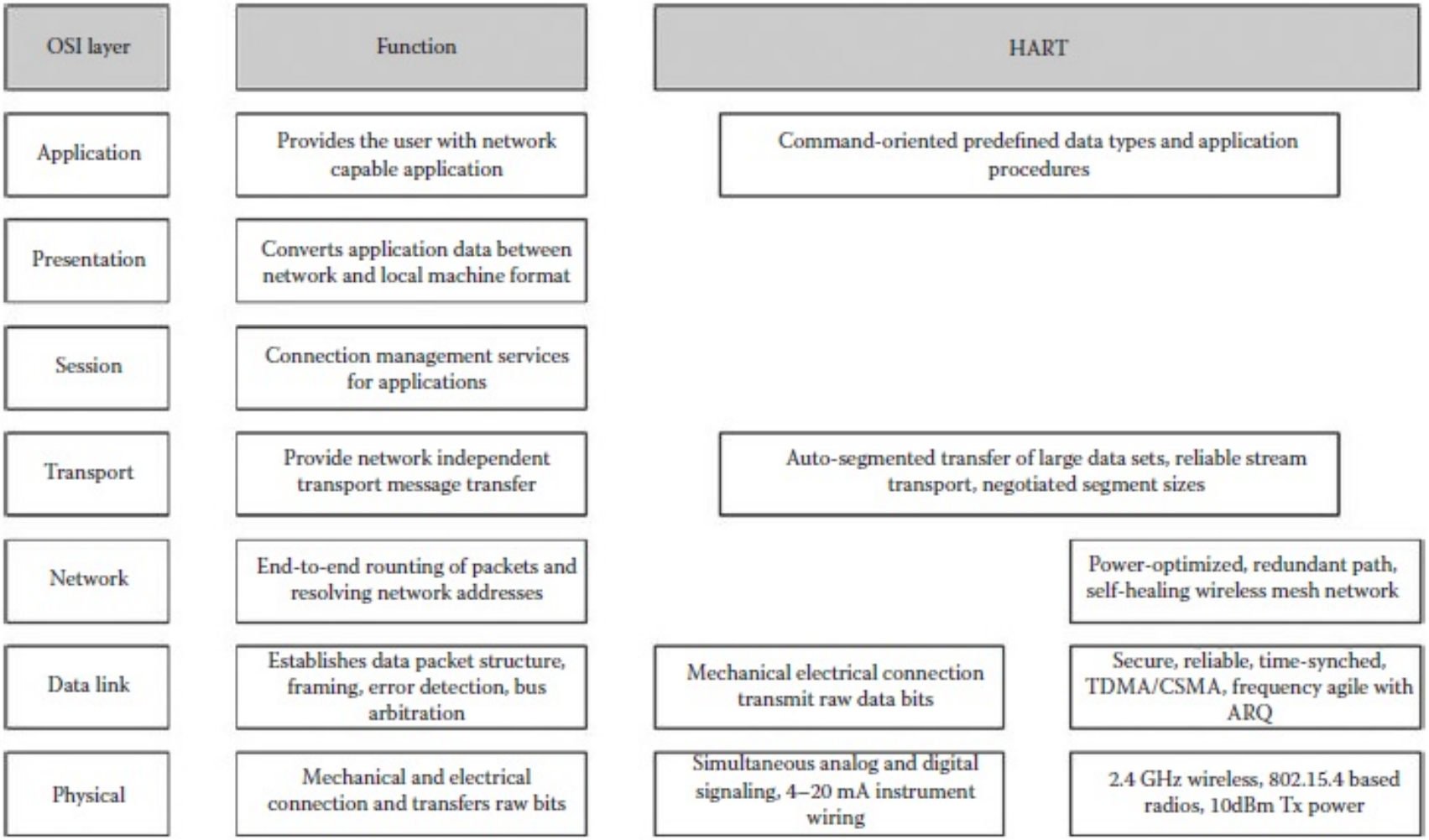

FIGURE 8.8 HART communication layers.

Wired Protocol

PHYSICAL LAYER:

- Data transmission between masters and field devices is physically realized by superimposing an encoded digital signal on the 4–20 mA current loop.

- The physical layer defines an asynchronous half-duplex interface that operates on the analog current signal line. To encode the bits, the FSK method, based on the Bell 202 communication standard, is used. Digital value 0 is assigned frequency 2200 Hz, and digital value 1 is assigned frequency 1200 Hz.

- HART masters are connected in parallel to the field devices.

- HART wiring in the field usually consists of twisted pair cables.

Wired Protocol (Contd..)

DATA LINK LAYER:

- The data link layer provides a reliable, transaction-oriented communication path to and from field devices for digital data transfer.

- The data link layer supports the application layer above it and requires services from the physical layer below it.

- Divided into two sub layers: the *logical link control* responsible for addressing, framing, and error detection; and the *medium access control* that controls the transmission of messages across the physical link.

The elements of the HART frame are summarized as follows:

- The *delimiter* is the first field in a HART message. It is used for message framing by indicating the position of the byte count.

- Three frame types are supported by the HART data link layer STX(0x2) indicates master to a field device, STX is generally Start of the transaction ACK(0x6) Salves response to the STX, and finally the BCK(0x1) burst acknowledge frame periodically transmitted by a burst-mode device.

Wired Protocol(Contd..)

- The *address* field can be short or long. The protocol supports both five (5) byte *unique* addresses and one (1) byte polling addresses.
- The *expansion* bytes are optional. This field is 0–3 bytes long and its length is indicated in the delimiter.
- The *command* byte encodes the master commands of the three categories: universal, common practice, and device-specific commands.
- The *byte count* character indicates the message length, which is necessary since the number of data bytes per message can vary from 0 to 25.
- The *data* field is optional and consists of an integral number of bytes of application layer data.
- The response message includes two status bytes at the beginning of the data portion of the message.
- This *check byte* field is 1 byte long. The check byte value is determined by a bitwise exclusive OR of all bytes of a message including the leading delimiter.

Wired Protocol(Contd..)

TRANSPORT LAYER:

- The *block data transfer* mechanism is best classified as a transport layer service.

- The HART transport layer is fully described in HART 7 and is utilized as part of the WirelessHART specification.

APPLICATION LAYER:

- The communication routines of HART master devices and operating programs are based on HART commands that are defined in the application layer of the HART protocol.

- The field devices immediately respond to a request by sending an acknowledgment that can contain requested status reports and/or the data of the field device.

WirelessHART Protocol

- Includes One extra layer Network Layer.

PHYSICAL LAYER:

- The WirelessHART physical layer is based on the IEEE 802.15.4-2006 2.4 GHz DSSS physical layer, which includes 15 of 16 possible RF channels. WirelessHART fully conforms to IEEE 802.15.4-2006.

DATA LINK LAYER:

- The WirelessHART data link layer (DLL) is based on a fully compliant IEEE 802.15.4-2006 MAC.

- To manage timeslots, the concept of a *superframe* is introduced that groups a sequence of consecutive timeslots.

- All superframes in a WirelessHART network start from the ASN (absolute slot number) 0, the time when the network is first created.

WirelessHART Protocol(Contd..)

In WirelessHART, a transaction in a timeslot is described by a vector: *{frame id, index, type, source address, destination address, channel offset}*

- frame id identifies the specific superframe
- index is the index of the slot in the superframe
- type indicates the type of the slot (transmit/receive/idle)
- source address and destination address are the addresses of the source device and destination device
- channel offset provides the logical channel to be used in the transaction.

NETWORK LAYER:

- DLL moves packets between devices, hop by hop, the network layer moves packets end-to-end within the wireless network.

- Network layer security provides end-to-end data integrity and privacy across the wireless network.

WirelessHART Protocol(Contd..)

TRANSPORT LAYER:

- The WirelessHART transport layer provides a reliable, connectionless transport service to the application layer.
- When selected by the application layer interface, packets sent across the network are acknowledged by the end device so that the originated device can retransmit lost packets.

APPLICATION LAYER:

- The application layer is HART. Because of this, access to WirelessHART is readily available by most host systems, handhelds, and asset management systems.

OUTLINE

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- HART Commands
- HART Communication Stack
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- WirelessHART Tools
- Installation
- Application & Future Trends

System Tools

System Tools section talks about how the HART devices are connected to the Host system.

- HART point-to-point Interface
- HART multidrop interface
- Utilizing FTA with legacy control systems
- Hosts with limitations on Data handling
- Hosts with Pass-through messages
- Utilizing Device Configuration(DDL)

OUTLINE

- Introduction
- HART Device Networks In Detail
- HART Architecture
- HART Communication Modes
- HART Network Topologies
- HART Commands
- HART Communication Stack
- System Tools
- WirelessHART Tools
- Installation
- Application & Future Trends

WiredHART Tools

- WirelessHART adaptors act as master devices for traditional wired HART devices and present them as subdevices on a WirelessHART network.

- An enhanced HART tool could interact with these subdevices just like with any other HART devices.

Special new tools are available for WirelessHART:

- Wi-Htest

- Wi-Analysis

- WirelessHART handheld device

WirelessHART Tools (Contd..)

Wi-HTest

Wi-Analysis

OUTLINE

- Introduction
- HART Device Networks In Detail
- HART Architecture
- HART Communication Modes
- HART Network Topologies
- HART Commands
- HART Communication Stack
- System Tools
- WirelessHART Tools
- Installation
- Application & Future Trends

Planning And Installation

WIRED HART:

- Installation practice for HART communicating devices is the same as for conventional 4–20 mA instrumentation.

- Most installations are well within the 3,000 m (10,000 ft) theoretical limit for HART communication.

- HART is often used in IS installations. IS is a method of providing safe operation of electronic process control instrumentation in hazardous areas.

- IS systems keep the available electrical energy in the system low enough to prevent ignition of the hazardous atmosphere.

Planning And Installation (Contd..)

WirelessHART:

- WirelessHART network may be configured similarly to a wired HART network.
- The gateway is the remote I/O system connecting wireless devices and adaptors to DCSs, PLCs, and other plant automation systems.
- The gateway has one or more access points that connect wireless devices to the gateway.
- Access points can be geographically dispersed from the gateway electronics and in general should be located near the devices to which they connect.
- A key consideration is the number of devices that may be connected.
- Estimate the average bandwidth consumed by a WirelessHART network

OUTLINE

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Applications

EXAMPLE: BIOREACTOR

- The HART communication protocol enables companies to make sure measurements are as efficient, accurate, and timely as possible.

- Control and monitoring applications are ideal for a HART point- to-point configuration. The HART network 4–20 mA fast update rates are ideal for pressure and flow measurements.

- Digital measurements may be used to communicate actual valve position as well as other parameters.

The user configures the following information for all network devices that are accessed through the HART host interface:

- Device Tag—which uniquely identifies the device
- Measurement value(s) that are to be accessed in the network device
- How often each measurement value is to be communicated to the gateway

Applications(Contd..)

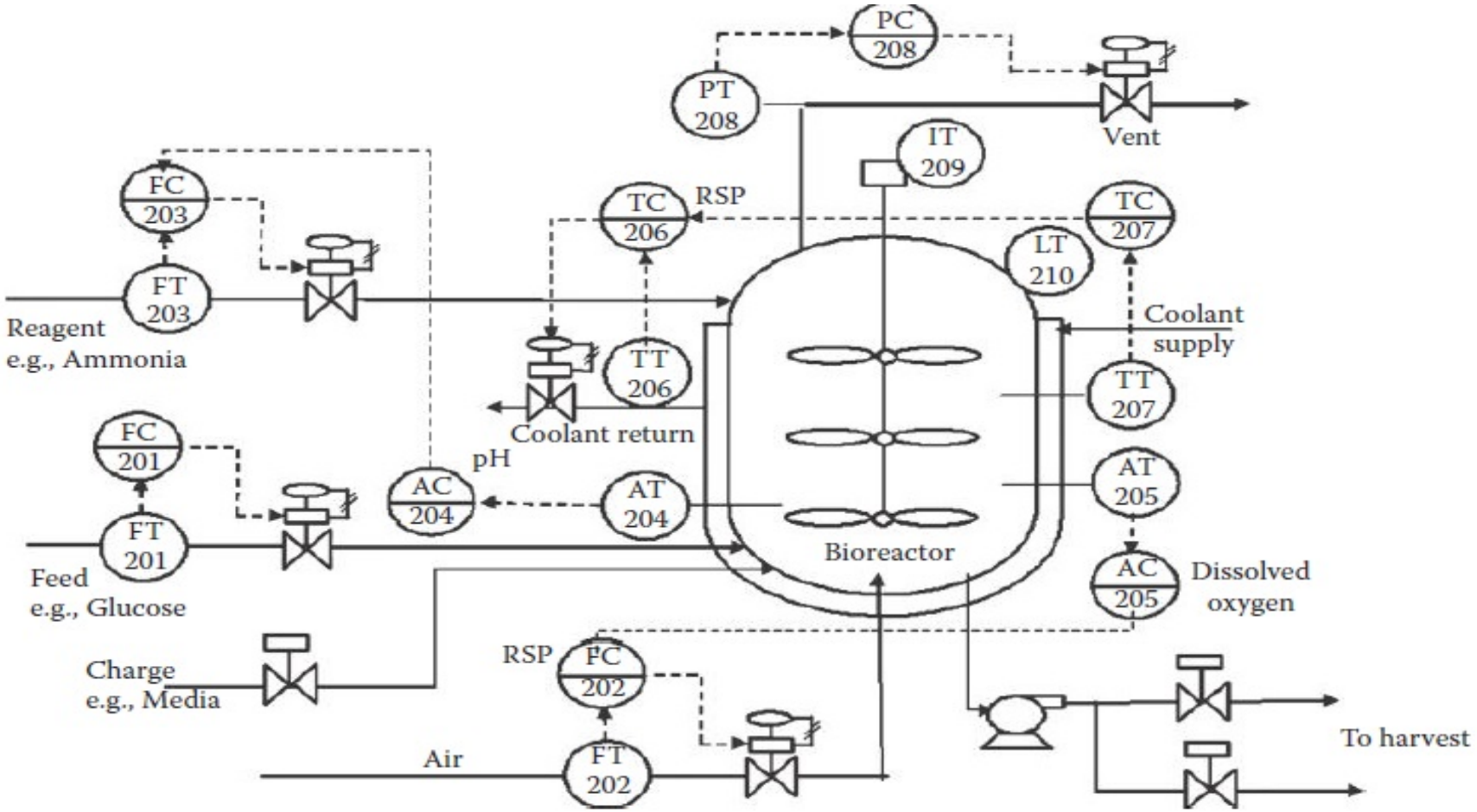

FIGURE 8.21 Bioreactor process.

Applications(Contd..)

TABLE 8.10 Instrument and Valve List for Bioreactor

Category	Device	Measurement	Scan Rates (s)
Measurement	C1	Reactor level (LT210)	16
	C2	Feed flow (liquid—FT201)	1
	C3	Reactor gas pressure (PT208)	1
	C4	Reactor temperature (TT207)	4
	C5	Agitator amps (IT209)	8
	C6	Return water temperature (TT206)	16
	C7	Reagent flow (FT203)	1
	C8	Air flow (FT202)	1
	C9	Dissolved oxygen (AT205)	4
	C10	pH (AT204)	4
Regulating valve	A1	Feed flow (FV201)	1
	A2	Reagent flow (FV203)	1
	A3	Coolant flow (FV206)	1
	A4	Vent flow (FV208)	1
	A5	Air flow (FV202)	1
Blocking valve	B1	Charge flow (FZ211)	1
	B2	Harvest flow (FZ212)	1
	B3	Harvest flow (FZ213)	1

Future Trends

- Wired HART and WirelessHART continue to build on the innovation that was started in the late 1980s.

What are the business drivers?

- All business performance is based on value that can be generated from its assets. These assets range from people and materials, to intellectual content, to physical properties.
- Plants are becoming much more integrated with business systems.

How will the device infrastructure evolve to support these business drivers?

- Gaining process insight involves an increased number of measurements, providing more diagnostics on the devices providing the measurements, providing diagnostics on the process that the devices are part of, and moving things online that were in the past done manually.
- In the first case, many plant infrastructures today are ill equipped to report advanced diagnostics. Wireless allows these measurements to be communicated on an alternative infrastructure.

Future Trends(Contd..)

- In other cases, the type of equipment, for example, rotating equipment, made it difficult to take measurements. It is a lot easier to attach devices to this kind of equipment and let the wireless infrastructure take care of the communications.
- In still other cases where state-of-the-art was manual measurement, wireless makes it cost effective to periodically take these measurements and communicate them
  - E.g., new devices are being designed and built to measure vibration and communicate signal values and diagnostics back to online centralized systems.

So what does this mean for HART?

- HART today is the workhorse of the industry. There is little evidence to suggest that this will change anytime soon.

- In this light, the most recent additions such as discrete devices and burst mode enhancements continue to be released for both wired and wireless technologies. Innovation will continue, and both wired and wireless devices will be there to serve users.

THANKS