Wireless HART

Motivation

WirelessHART (Wireless **H**ighway **A**ddressable **R**emote **T**ransducer) is the first open wireless communication standard specifically designed for process measurement and control applications for industrial automation [1].

Basic concept

The new WirelessHART operates in the unrestricted 2.4GHz ISM radio band and is specifically targeted to solve these problems and provide a complete solution for process control applications. At the very bottom, it adopts IEEE 802.15.4 low-rate wireless personal area networks (LR-WPANs) as the physical layer. On top of that, WirelessHART defines its own time-synchronized MAC layer. Some notable features of WirelessHART MAC include strict 10ms time slot, network wide time synchronization, channel hopping, channel blacklisting, and industry standard AES-128 ciphers and keys. The network layer supports self-organizing and self-healing mesh networking techniques. In this way, messages can be routed around interferences and obstacles. WirelessHART also distinguishes itself from other public standards by maintaining a central network manager. The network manager is responsible for maintaining up-to-date routes and communication schedules for the network, thus guarantee the network performance.

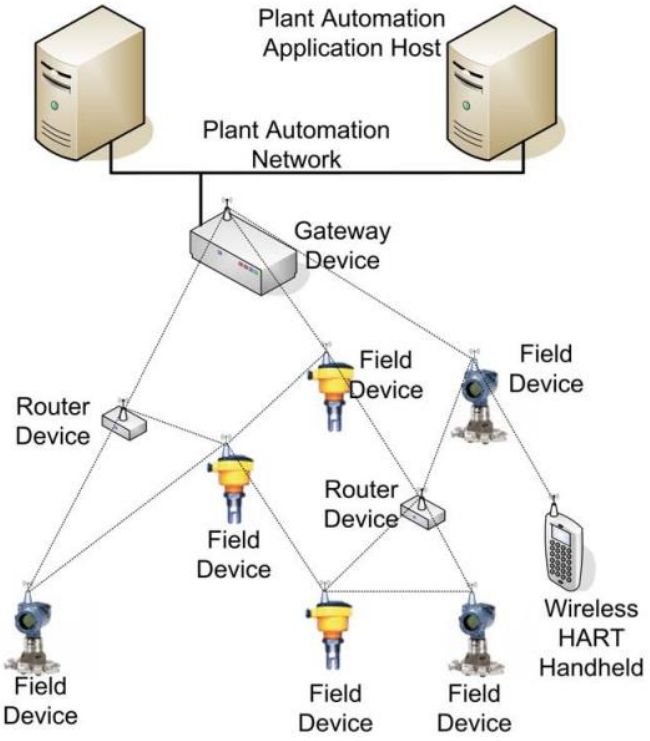

Figure 1 WirelessHART Mesh Networking

Basic elements (Figure 1) of a typical WirelessHART network include:

(1) **Field Devices** that are attached to the plant process,
(2) **Handheld** which is computer used to configure devices,
(3) **A gateway** that connects host applications with field devices and
(4) **A network manager** that is responsible for configuring the network.

WirelessHART Architecture

Data Link Layer

In Figure 2 an overall design of the data dink layer is given, which consists of:

1. *Interfaces*

The interface between the MAC and PHY layer describes the service primitives provided by the physical layer, and the interface between the MAC and Network layer defines the service primitives provided to the network layer.

2. *Timer*

Timer is a fundamental module in WirelessHART. It provides accurate timing to ensure the correct operating of the system.

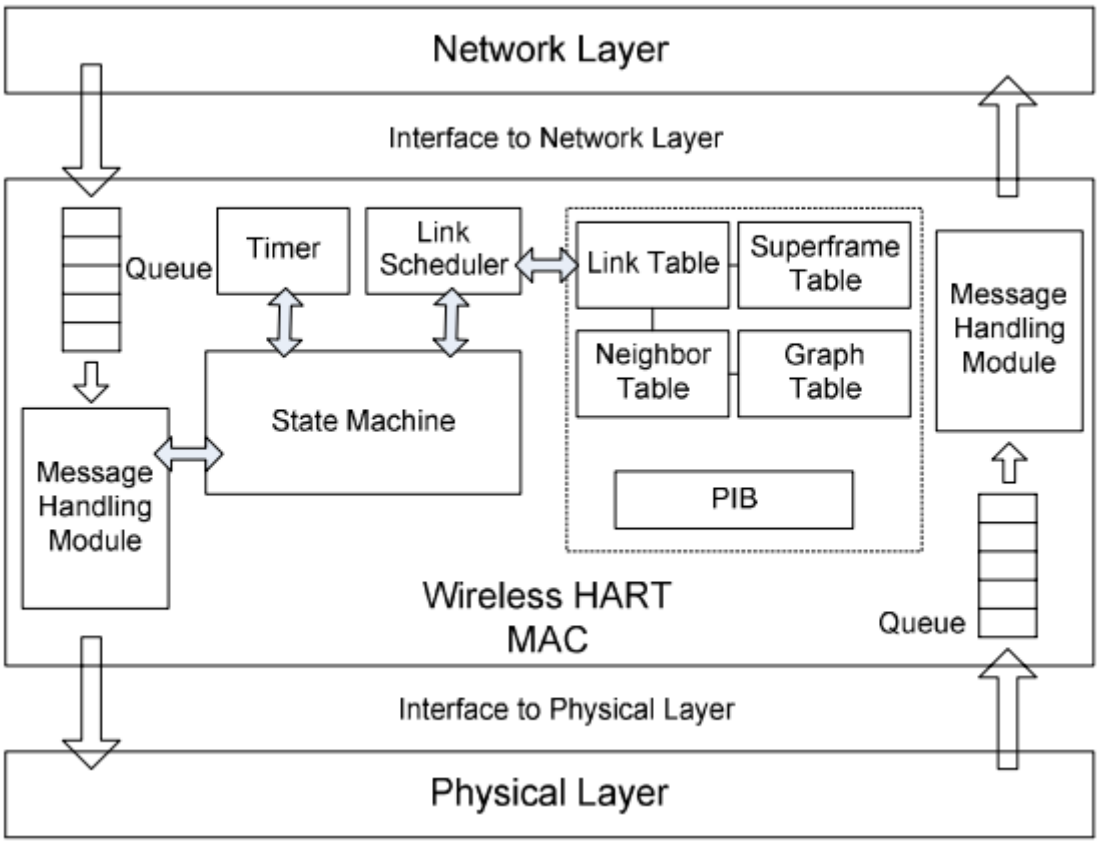

Figure 2 WirelessHART Data Link Layer Architecture [1].

3. *Communication Tables*

Each network device maintains a collection of tables in the data link layer. The superframe table and link table store communication configurations created by the network manager; the neighbor table is a list of neighbor nodes that the device can reach directly and the graph table is used to collaborate with the network layer and record routing information.

4. *Link Scheduler*

The functionality of the link scheduler is to determine the next slot to be serviced based on the communication schedule in the superframe table and link table. The scheduler is complicated by such factors as transaction priorities, the link changes, and the enabling and disabling of superframes. Every event that can affect link scheduling will cause the link schedule to be re-assessed.

5. *Message Handling Module*

The message handling module buffers the packets from the network layer and physical layer separately.

6. *State Machine*

The state machine in the data link layer consists of three primary components: the TDMA state machine, the XMIT and RECV engines. The TDMA state machine is responsible for executing the transaction in a slot and adjusting the timer clock. The XMIT and RECV engine deal with the hardware directly, which send and receive a packet over the transceiver, respectively.

MAC Protocol Description

The main tasks of the MAC (Medium Access Control) protocol are:

- slot synchronization,
- identification of devices that need to access the medium,
- propagation of messages received from the Network Layer and
- to listen for packets being propagated from neighbors.

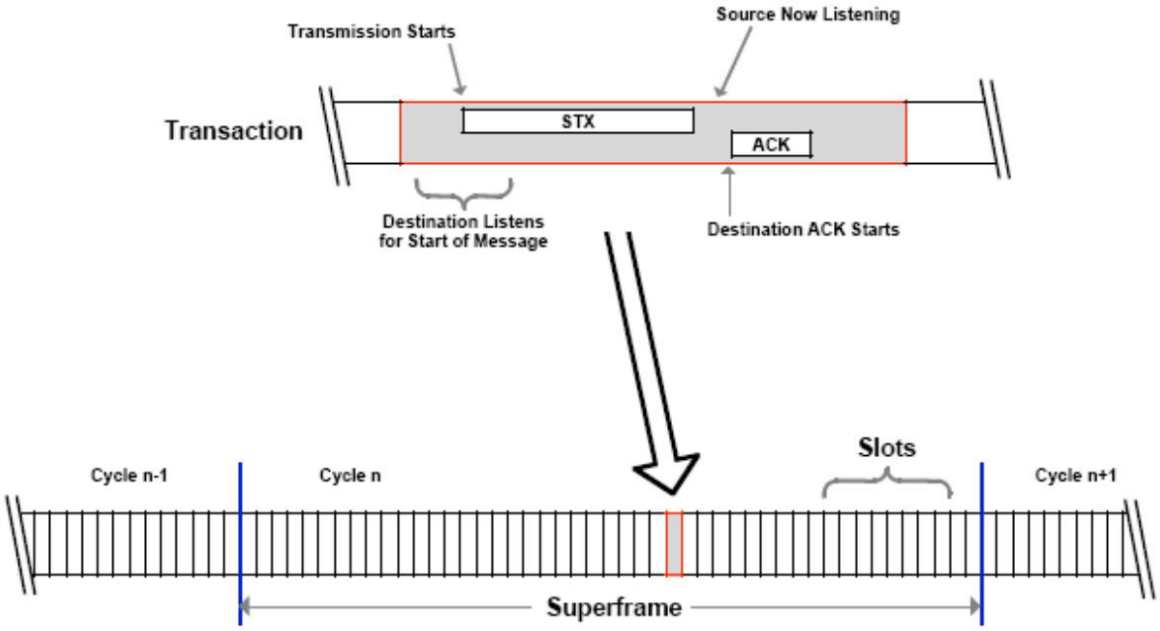

Figure 3 SuperFrame Structure

The Medium Access Control (MAC) sub-layer is, hence, responsible for propagating Data Link packets (DLPDU) across a link [2]. To permit this, the device includes:

- Tables of neighbors, superframes, links, and communication graphs between the devices,
- A link scheduler that evaluates the device tables and
- State machines that control the propagation of packets through the MAC sub-layer.

Time Division Multiple Access (TDMA)

WirelessHART uses Time Division Multiple Access (TDMA) and channel hopping to control access to the network. TDMA is a widely used Medium Access Control technique that provides collision free, deterministic communications. It uses time slots where communications between devices occur. A series of time slots form a TDMA superframe can be seen in Figure 4.

For successful and efficient TDMA communications, synchronization of clocks between devices in the network is critical. Consequently, tolerances on time keeping and time synchronization mechanisms are specified to ensure network-wide device clock synchronization. It is imperative that devices know when the start of a slot occurs. Within the slot, transmission of the source message starts at a specified time after the beginning of a slot. This short time delay allows the source and destination to set their frequency channel and allows the receiver to begin listening on the specified channel. Since there is a tolerance on clocks, the receiver must start to listen before the ideal transmission start time and continue listening after that ideal time. Once the transmission is complete, the communication direction is reversed and the destination device indicates, by transmitting an ACK, whether it received the source device DLPDU successfully or with a specific class of detected errors. To enhance reliability, channel hopping is combined with TDMA. Channel hopping provides frequency diversity, which can avoid interferers and reduce multi-path fading effects.

Shared Slot

WirelessHART allows to define shared slots in which more than one device may try to transmit a message. Consequently, collisions may occur within a slot. If a collision occurs, the destination device will not be able to successfully receive any source transmission and will not produce an acknowledgement to any of them. To reduce the probability of repeated collisions, source devices shall use random back-off delay when their transmission in a shared slot is not acknowledged. A device shall maintain two variables for each neighbor: Back-Off Exponent (BOExp) and Back-Off Counter (BOCntr).

Communication Tables

All devices maintain a series of tables that control the communications performed by the device. The tables controlling communication activities include:

- Superframe and Link tables.
- The Neighbor table.
- The Graph table.

Conclusion

WirelessHART uses 2.4GHz license free frequency band was specifically designed and optimized for industrial wireless sensor communications. Communication is coordinated with TDMA, which synchronizes the devices that make up the network in steps of 10 ms. This enables a highly reliable (collision free) network and reduces lag times during which a station must be active [3]. Since WirelessHART is built on IEEE 802.4.15 standard, it can also co-exist with other wireless networks. It is a self-healing network, it monitors paths for degradation and repairs itself and finds alternate paths around obstructions [4]. It also has robust security mechanisms, such as AES-128 encryption, code management, and authentication, so that data and the network are protected.

References

[1] Paper by Jianping Song “WirelessHART: Applying Wireless Technology in Real-Time Industrial Process Control”, IEEE Real-Time and Embedded Technology and Applications Symposium, 2008

[2] Masters’ Degree Project by Mauro De Biasi “Implementation of a wirelessHARTsimulator and its use in studying packet loss compensation in networked control”, Stockholm, Sweden February 2008

[3] Web page “WirelessHART”, accessed 07.06.2021

[4] Web page “Wireless HART Communication Protocol Overview”, accessed on 07.06.2021.