

Radio Silence for Wireless Field Networks

Radio silence is a state in which all radios in an area have stopped transmitting. It is a common practice at many well head sites during well perforating to prevent the accidental detonation of perforating guns.

Introduction

The process of well perforating, or working with any explosive material, can be dangerous and precautions are needed to ensure that no outside interference will cause any accidental detonations. While Smart Wireless devices are extreme low power RF sources and they are certified to ensure they will not interfere with other electrical equipment, extra measures (radio silence) can be taken to provide reassurance of a safe operating environment.

This white paper will discuss how to apply radio silence to the entire wireless field network and how to restore the network to normal operations. A detailed report containing 3rd party lab validation will be made available upon request.

Normal Network Operation

A typical Smart Wireless Network consists of a Smart Wireless Gateway connected to a host system along with many Smart Wireless field devices communicating to the gateway. The field devices periodically send measurement data to the gateway (e.g. once per minute). Each field device communication is governed by a defined schedule determined by the network manager. The schedule is based on the communication needs of all the field devices, RF performance between devices and historic network performance measures.

Time synchronization is done during normal field device measurement communication, routing for other devices or with keep-alive messages. If a device does not have any measurements to send or messages to forward to the gateway for other devices, it must send keep-alive messages to its neighbors to ensure it stays time synchronized to the network. During normal operation, the gateway and field devices are time synchronized to less than 5 milliseconds.

When a multi-hop mesh network is functioning normally, the gateway or the routing device for the next hop closer to the gateway will reply to the originating device with an acknowledge message letting the device know its message was received. Embedded in this acknowledge message is a time synchronization. Once the originating device receives the acknowledgement/time synchronization, it goes to sleep until the next scheduled transmit time. If the originating device does not receive an acknowledgement, it waits until the next scheduled communication opportunity

to retry the message. These retries provide additional data reliability robustness beyond the benefits realized from the mesh network alone.

If a device does not receive a time synchronization, then the device will perform a series of fault condition actions. Before entering a passive listen only mode, the device issues a notice to all of its neighbors that it is disconnecting from the network. This triggers a cascading effect that rapidly places all devices in a passive listen only mode.

The fundamental characteristics of the Smart Wireless solution provides robust field device data reliability in a wide variety of environmental conditions.

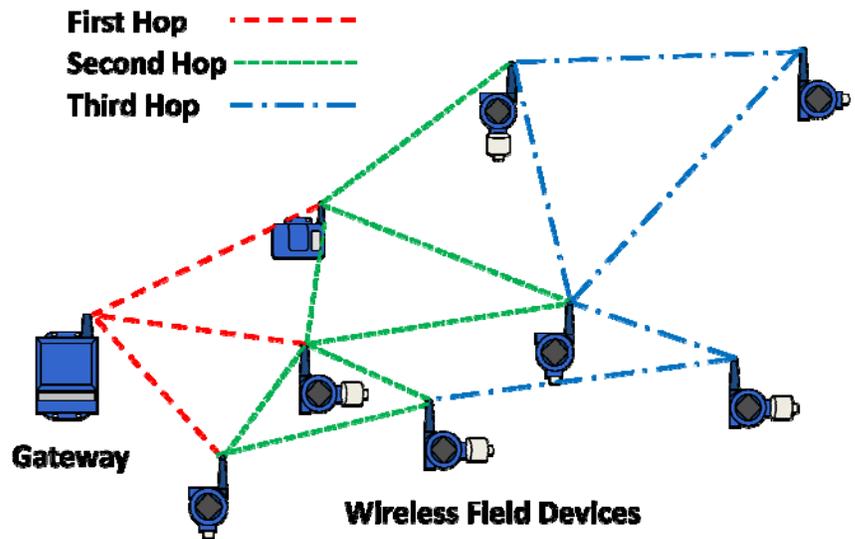
Radio Silence Process

Radio Silence for a Smart Wireless field network can be achieved by powering down the Smart Wireless Gateway. This action will force all devices in the network into their planned fault condition. Once the field devices have determined they can no longer communicate with the gateway, they stop communicating and go into a listen only mode. In this mode the device is only listening for advertisements from devices with the proper Network ID. Random RF noise or ill formatted messages are discarded and cannot force the radio out of passive mode.

Once the Smart Wireless Gateway is powered down, no communication to the gateway will be acknowledged. The field devices that are connected directly to the gateway continue to retry the messages destined to the gateway until all the retries are exhausted. Once the initial retries have failed, the devices send keep-alive messages for a short period of time. This is a last ditch effort to keep the network together. After eight keep-alive attempts have failed to be acknowledged, the device sends out a disconnect message to all devices connected to it and then transitions to the passive listening only state. This process takes 240 seconds to complete, regardless of the configured update rate of the devices.

Once the field devices closer to the gateway send out disconnect messages and enter the listening only state, the devices further out from the gateway also follow the same process. These devices will send out disconnect messages and then transition to the listening only state as well. This process continues until all the devices in the network have transitioned to the passive listening only state (receive only). This process is independent of network size (number of devices), and the configured update rate of the devices.

Figure 1. Smart Wireless Network



Given that the network follows this orderly process, all devices will transition to a receive-only state within 450 seconds. This is independent of network size or hop depth and it has been analyzed on a worst case scenario of 100 devices with a depth of 10 hops. Our recommendation is to add 100% margin on top of that and begin the process of radio silence 15 minutes prior to arming any explosives.

Recovery Process

To restore the network to normal operation, simply reapply power to the Smart Wireless Gateway. When the Gateway powers up it automatically starts to send advertisement messages. Devices will begin to join when they receive a valid advertisement with the proper Network ID. As devices close to the gateway join and are configured they also begin to advertise so devices further away from the gateway are able to join.

There is no need reconfigure any of the field devices. They respond automatically to the Gateway's advertisements. A typical network will reform in about 2 to 5 minutes. Very large networks in size and/or distance could take 10 to 20 minutes.

Summary

While wireless devices are extremely low power and have been certified to not interfere with other electronic equipment, radio silence provides the extra assurance required when working with explosive materials.

By removing power from the Gateway, all field devices will stop wireless transmissions after 15 minutes. The network can be restored by reapplying power to the Gateway and allowing the network to reform.

The process for achieving radio silence has been verified by a 3rd party test laboratory and the test findings will be made available upon request.

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Emerson Process Management
12301 Research Blvd., Building 3
Austin, Texas 78759
InfoCentral@EmersonProcess.com
www.EmersonProcess.com/Smartwireless