SmartDiagnostics® Application Note

Wireless Interference and SmartDiagnostics®

Publication Date: May 27, 2015

KCF Technologies, Inc.

Overview

The SmartDiagnostics® wireless network uses a proprietary protocol to communicate between the sensor nodes and wireless receivers. This application note describes the impact of SmartDiagnostics® wireless on a coexisting WiFi® network and the impact of the WiFi® on SmartDiagnostics® communications.

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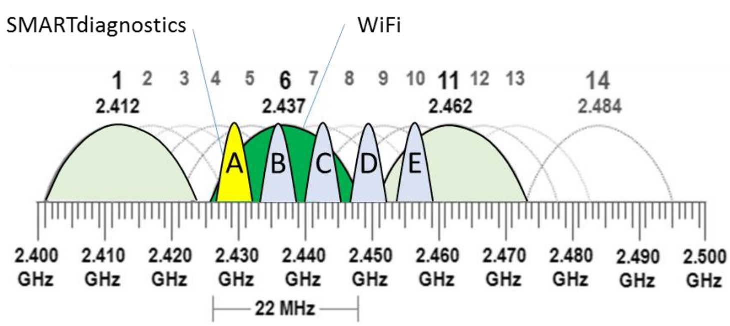
SmartDiagnostics® in the 2.4 GHz ISM Band

SmartDiagnostics® uses the 2.4 GHz ISM Radio Frequency (RF) band for the sensor communication because it is ideally suited for balancing energy efficiency and transmission range in industrial facilities. In contrast, the 915 MHz ISM band offers too low a data throughput to transmit large data sets efficiently and the 5.8 GHz band offers too short a range to practically apply in most industrial machine condition monitoring applications.

SmartDiagnostics® uses 5 channels shown in the following figure. For reference, these channels are overlaid on WiFi® spectral usage, which typically operates on the 1, 6, or 11 channels.

SmartDiagnostics® Channel	A	B	C	D	E
Center Frequency (MHz)	2429	2436	2443	2450	2457



Notice that SmartDiagnostics® channel D does not overlap with primary WiFi® channels 1, 6, and 11, which allows them to coexist without interfering. In the case where WiFi® Channel 6 is used, SmartDiagnostics® channels D and E can be used. Similarly, if WiFi® channels 1 and 11 are used, SmartDiagnostics® channels A, B, C can be used without interfering.

SmartDiagnostics® can use one or more of its 5 channels, depending on the particular application. Each channel typically supports 50 sensor nodes within a wireless coverage region defined by a perimeter roughly 200 feet from the receiver (PRN). Within a ~200 foot region, typically 250 sensors can be supported with a single Collection Server. Most industrial facilities can be logically broken into regions where Collection Servers are distributed to cover each region.

SmartDiagnostics® uses a transceiver that is similar to ones used by Bluetooth®. The SmartDiagnostics® wireless protocol, called DARTwireless™, is different than Bluetooth® because it is focused on ultralow power, low bandwidth consumption and supporting hundreds of devices. It uses a channel adaptations scheme to pick the best channels to use based on interference and internetwork load balancing across multiple receivers, but unlike Bluetooth®, it does not use frequency hopping.

The basic characteristics of the RF traffic generated by SmartDiagnostics® are as follows:

- Modulation – GFSK (same as Bluetooth®)
- Over the air rate - 2 Mbps
- Channel half-power bandwidth – 2 MHz
- Peak RF power – 15 dBm
- Typical range: 800' line-of-site, 100-300' industrial indoor

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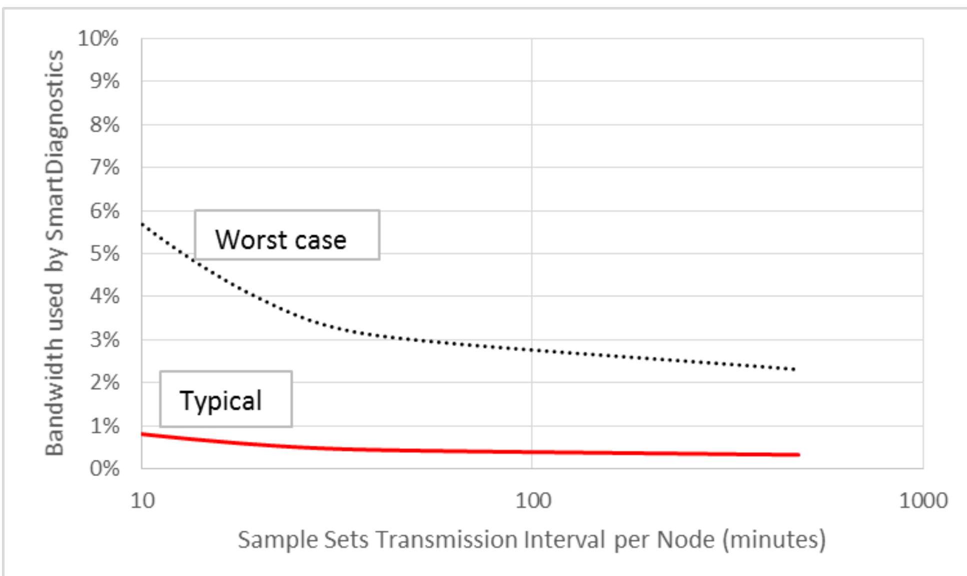
The SmartDiagnostics® primary sensor node, the SD-VSN-2 (Vibration Sensor Node), acquires data sets that contains 1650 data points. These data sets are transmitted to receivers immediately after the data is acquired. This occurs on a user configurable interval that depends on the particular application. Data sets are typically acquired and transmitted as frequently as once per minute to once per hour.

In addition to the data transmissions, the SmartDiagnostics® network also sends a heartbeat packet on a fixed 4 second interval. This heartbeat sustains the network and allows commands to be sent to the nodes on a timely basis.

All communication between the sensor nodes and the receiver is acknowledged with a confirmation packet sent by the receiving transceiver. This enables the node to recognize if it should retransmit the data packet.

While the network is being setup or reconfigured, sensor nodes will automatically search for a receiver channel that is active. During this process, the nodes will send small notification packets every few seconds, consuming a small amount of bandwidth, which is much lower than typical operation.

The bandwidth consumed by a 100 sensor SmartDiagnostics® network is shown in the following figure. Bandwidth in this case is defined as the total percent on-air time used by the sensors. The range of bandwidth usage shown by the two curves represent a typical case (red line) where the sensors are not retransmitting data and an extreme case (black dot line) where every piece of data is retransmitted a maximum number of times.



The figure shows that 100 nodes transmitting large (1650 point) data sets every 30 minutes consumes between 0.5-3.4% of a single, narrow band, channel (only one of the 5 channels shown in the frequency spectrum).

In the following figure, the same data is shown for the case where the sample set transmission interval is fixed at 30 minutes and the number of nodes in a given wireless coverage region is varied.

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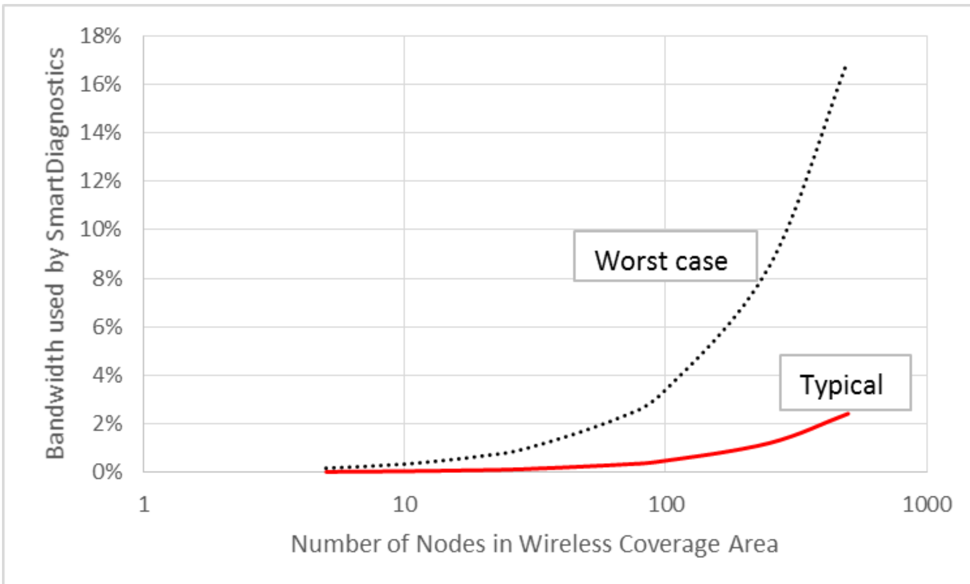


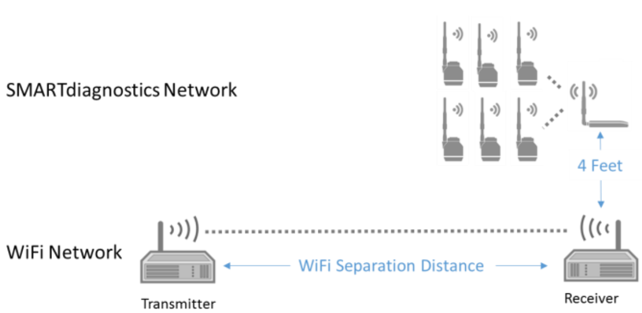
Impact of SmartDiagnostics® on WiFi®

The impact of SmartDiagnostics® wireless bandwidth usage on the function of other wireless devices is difficult to universally assess analytically. To examine this in a meaningful way, a case where SmartDiagnostics® is operated in an active WiFi® channel concurrently was evaluated. In particular, SmartDiagnostics® channel A (shown in yellow in the frequency spectrum plot) was configured to overlap with WiFi® channel 6 (green area) in the following experimental test.

A worst case condition was chosen to examine how well WiFi® and SmartDiagnostics® coexistence. In this test, 60 sensor nodes were set to transmit data sets every 1 minute and were located in the proximity of a WiFi® network.

60 sensor with 1 minute collection interval (test condition)

≡ 650 sensors with 30 minute collection interval



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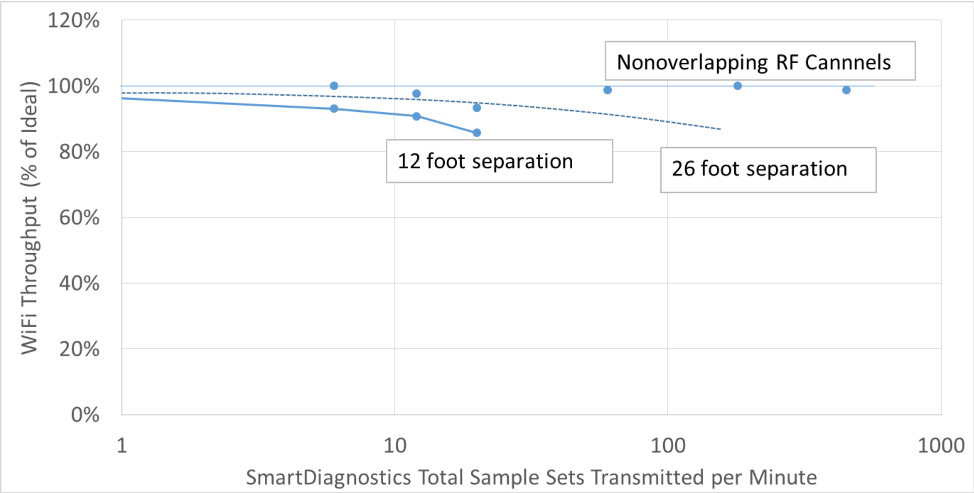
The WiFi® network used IEEE 802.11g CISCO access points (Q87-E800). The access point was specified to output a maximum power of 23 dBm. The SmartDiagnostics® power level was set at its default of 15 dBm with a 3dBi dipole antenna. The impact of SmartDiagnostics® on WiFi® was assessed by evaluating the transmission speed of a large file that was sent over the WiFi® network. This file transfer forced the WiFi® network to attempt to transmit nearly continuously over the evaluation period. The ratio of the baseline speed (without the SmartDiagnostics® network) to the speed while coexisting with SmartDiagnostics® is shown in the following figure.



This assessment was made for a case where the separation distance between the WiFi® Access Point (transmitter location) was 12' and 26' away from the SmartDiagnostics® network. The horizontal axis shows SmartDiagnostics® total sample sets transmitted per minute, which can be roughly calculated as the number of sensors in a wireless coverage area divided by the average data set transmission interval (e.g., 650 sensors/30 minutes = 22 total sample sets transmitted per minute).

SmartDiagnostics® sensor bandwidth is primarily consumed by the data acquisitions rather than the heartbeat to sustain the network for acquisitions more frequently than an acquisition every 30 minutes. In this case, the above total sample sets transmitted per minute generalization is valid.

The same test was done with WiFi® using channel 1, which doesn't overlap with SmartDiagnostics® channel A. The non-overlapping case is shown by the orange line the figure above.

Notice that the separation distance between the WiFi® transmitter and the SmartDiagnostics® sensors makes a large difference in the WiFi® performance. This is shown in further detail in the following figure.

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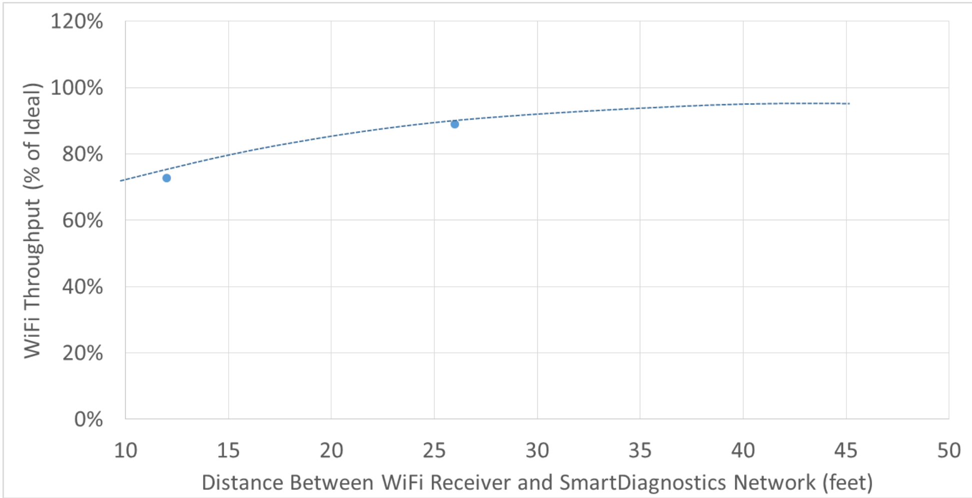
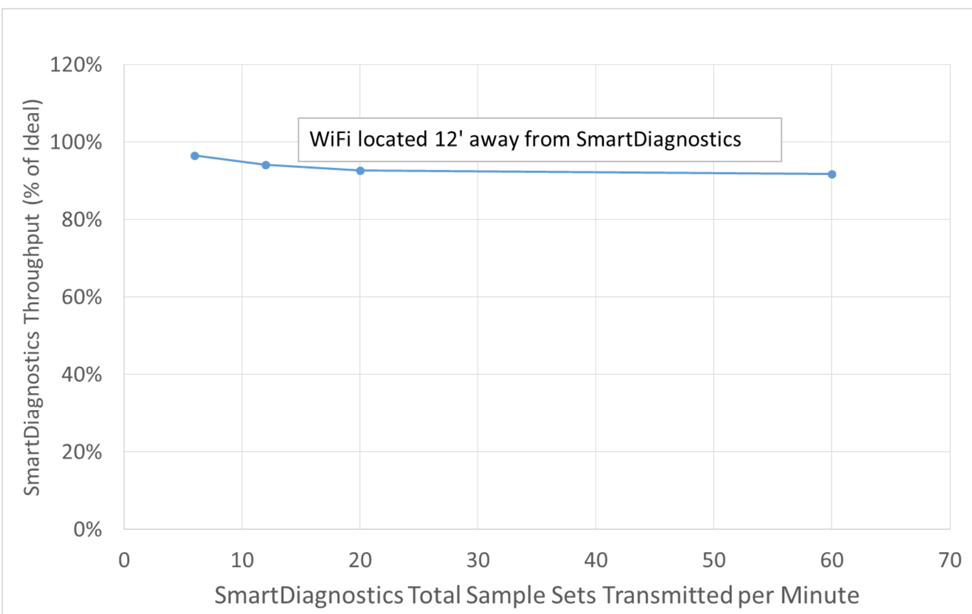


Impact of WiFi® on SmartDiagnostics®

WiFi® can have an impact on throughput of the SmartDiagnostics® network. This was assessed experimentally using the same setup as was described for examining the impact of SmartDiagnostics® on WiFi®. The same generalization for the horizontal axis is used, which is given in the following plot as the total sample sets transmitted by all the sensor nodes per minute.



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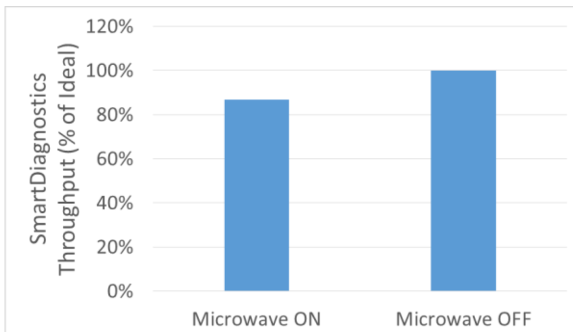
Again, notice that locating the WiFi® transmitter at a distance of 12' from SmartDiagnostics® network, the SmartDiagnostics® throughput was 94%. Also note that in this example case, the SmartDiagnostics® transmission interval has little impact on the SmartDiagnostics® throughput. This is expected considering that WiFi® was attempting to transmit continuously over the evaluation period.

Impact of Microwave Ovens on SmartDiagnostics®

Considering that microwave ovens use the 2.4 GHz band and can potentially impact the throughput of SmartDiagnostics®, a test was done to examine potential interference. The test consisted of locating an 1100 Watt microwave oven next to (within 4 feet of all nodes) the SmartDiagnostics® test setup. The oven was run continuously at full power during the test. The throughput of the SmartDiagnostics® network with the oven ON and OFF is shown in the figure below. In this extreme case, the throughput of SmartDiagnostics® was reduced by 13%.



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