

Reducing Interference in Wireless Networks: Evaluating the Effectiveness of Multi-Band vs. Single-Band Radios in Industrial Environments

Enterprises recognize mobility as a strategic business and IT priority to drive productivity, business transformation, and competitive differentiation in the global economy. As a result, industrial markets such as mining, gas and oil, utilities, transportation, military, and government have experienced significant growth of wireless networks and mobile devices.

Simultaneously, radio-frequency (RF) interference has become one of most prevalent causes of outages and unstable wireless connectivity and can come from a number of sources, including:

- **Physical Landscape:** Manmade and natural obstructions such as trees, hills, and buildings can cause radio waves to be reflected, resulting in multipath interference. Severe weather conditions such as heavy rain, snow, and fog can also create interference.
- **Other RF Devices:** A variety of electronic devices such as cordless phones, wireless video cameras, Bluetooth-enabled devices, and microwave devices can cause interference.
- **Other Wireless Networks:** Competing wireless networks in the area can interfere with your wireless network.
- **Physical Distance:** The further the distance is between the sending device and the receiving device, the weaker the signal will be and the higher likelihood of being impacted by interference.

Unique Challenges in Industrial Enterprises

Industrial organizations experience unique interference challenges due to constantly changing ground elevations, landscapes, and weather conditions as personnel, vehicles, and equipment traverse wide expanses of terrain. Open-pit mines and oil-and-gas fields span large geographic areas where on-site personnel and fleets of high-cost, high-tech vehicles constantly move across changing terrain through all kinds of weather. Buses and trains often travel across vast, remote areas where distance can increase the potential for interference. Military and defense personnel operate in hostile terrain and weather extremes. And, first responders are frequently on the move to protect and serve citizens in both urban and rural areas. In all of these scenarios, anytime, anywhere access to applications and data is vital. If interference causes outages or unreliable communications, lives can be at risk, operating costs can spiral out of control, and expensive assets can be damaged.



Combating Interference

While it is not possible to totally eliminate interference, you can greatly mitigate its negative effects. Systems that support multiple antennas can increase signal strength and reduce the effects of interference. Although strategic placement of antennas can help manage interference, by themselves, antennas are not the complete cure. One of the most effective ways to overcome interference is to utilize multi-transceiver, multi-band radios rather than single-transceiver, single-band radios. Both types of radios are certainly capable of sending and receiving voice, video, and data. However, when interference threatens application and data access, multi-transceiver radios can improve connectivity significantly.

In a single-transceiver radio, you have one device, called a transceiver, to send and receive information, and the transceiver can support one RF band over which information can be transmitted. If that band experiences interference from any source, the signal will degrade and may drop completely. You can somewhat relieve the problem by utilizing two or more single-band radios at each end of a connection. However, there is a more efficient way to overcome interference.

Multi-transceiver radios can operate with multiple transceivers, and each transceiver can support a specific RF band. Rather than having one direction to a destination, you have several directions. If one or more frequencies experience interference, information can be transmitted over other bands that are not experiencing interference.



Rajant BreadCrumb® Wireless Nodes Mitigate Interference

Rajant Kinetic Mesh networking technology is designed and engineered to address the unique wireless requirements of industrial organizations and provide reliable, always-on communications to the people and assets that traverse their private wireless networks. Each Kinetic Mesh private wireless network starts with Rajant BreadCrumb wireless radios, or nodes, which can be bolted to trucks, convoys, and other moving equipment, as well as mounted in fixed locations. Rajant InstaMesh® networking software is responsible for the continuous transmission of all wired and wireless connections within a Kinetic Mesh network. It continuously determines the best action for each data packet flowing through the network with no central management node or single point of failure.



BreadCrumb LX5



BreadCrumb ME4



BreadCrumb JR2

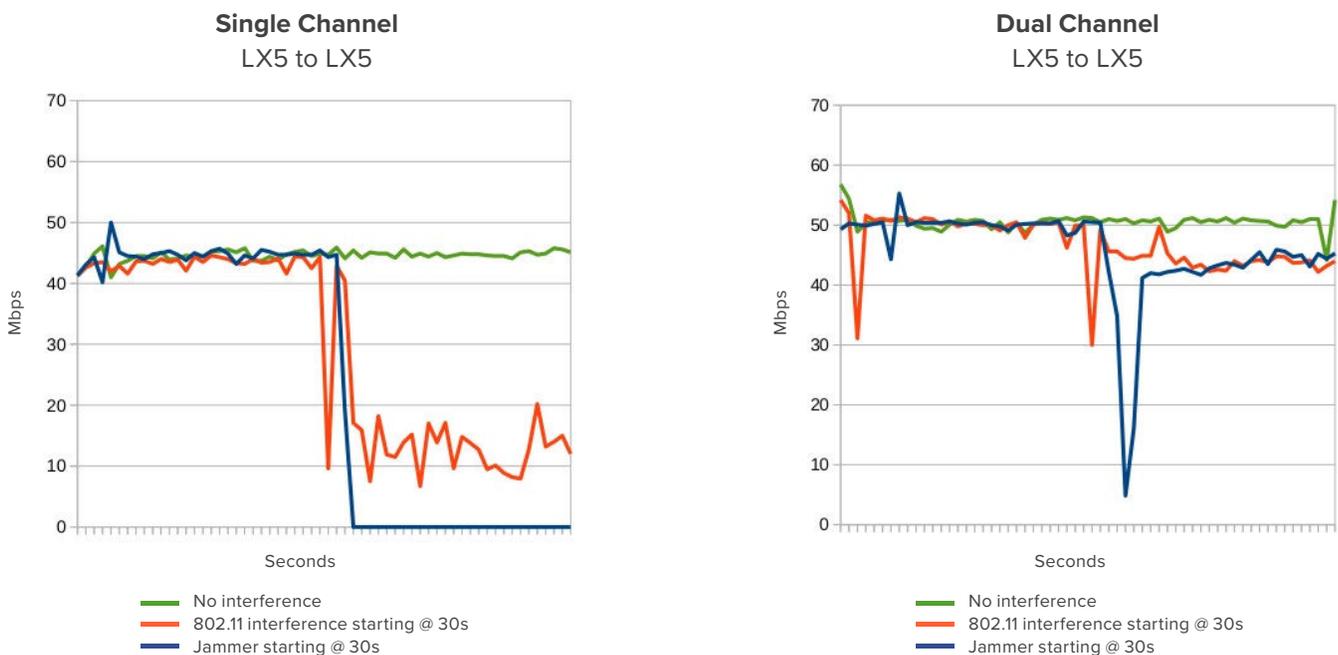
Currently, we offer three BreadCrumb models as shown above. The LX5 and ME4 BreadCrumb wireless nodes are multi-transceiver, multi-band devices, and the JR2 is a single-transceiver, single-band device. The LX5 supports up to four transceivers and up to four radio frequencies, and the ME4 supports up to up to two transceivers and up to two radio frequencies. Using the InstaMesh software, BreadCrumb nodes can simultaneously transmit information across different frequencies and will intelligently send data over an available frequency when another frequency experiences interference. In addition, the LX5 and ME4 models support multiple antennas, allowing you to further reduce interference.

Test Methodology and Results

Rajant engineering staff conducted tests on BreadCrumb LX5 wireless nodes with InstaMesh networking software to show how single-transceiver and multi-transceiver point-to-point radio configurations react to interference. Two different point-to-point configurations were used:

- 1. Two single-channel LX5's** with a single-transceiver LX5 at each end of the connection: In this test, each LX5 was configured with only one transceiver. Although InstaMesh software was present on each node, there was no opportunity to avoid interference since no alternate connections were available.
- 2. Two dual-channel LX5's** with two radio transceivers at each end of the connection: Each transceiver was enabled on a different frequency. In this scenario, the InstaMesh networking software was able to send packets via different radios within the same BreadCrumb node.

Point to Point TCP Throughput



Three interference models were used for the tests as follows:

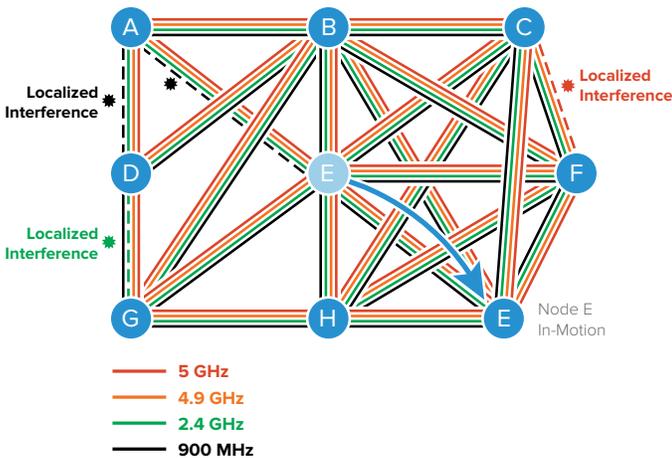
- 1. No Interference:** This model (illustrated by the green line) was used as the baseline for ideal circumstances.
- 2. 802.11 UDP Packets on the Primary Channel:** This model represented typical interference (represented by the red line) that can occur in an urban or campus environment or any place where competing 802.11 systems are deployed.
- 3. 100% Duty Cycle Transmission (labeled “Jammer”) on the Primary Channel:** This represents extreme interference that can be caused by intentional jamming using jamming equipment or by devices such as analog phones and cameras that make no effort to share spectrum.

In both tests, higher data rates were possible before the interference and jammer were introduced. The most obvious results can be seen in the “Jammer” tests. In the Single Channel diagram, you can see that the jammer completely stopped the transmission of data. Effective interference avoidance was achieved in the Dual Channel test through the use of the dual-radio, dual-frequency capabilities, although the jammer did cause a momentary drop to 5 Mbps. With the exception of the momentary drop in throughput, the dual channel node was able to sustain approximately 45 Mbps even in the presence of interference and jamming. While these tests were performed using point-to-point configurations to provide a controlled test case, similar results would apply in a mesh configuration.

Multi-Band Advantages

Because multi-transceiver, multi-band radios offer several ways to transmit information from a source to a destination, they have increased interference tolerance. It is important to note that certain competitive wireless networks that utilize dual frequencies assign one frequency to client communications and one frequency to backhaul communications. Such configurations are really single-band radios because each frequency is assigned to one specific task.

In a Kinetic Mesh network, our multi-band radios can function as digital repeaters, meaning they can receive a radio signal and forward it, allowing the mesh network to pass information packets from one node to another. A digital repeater that makes use of additional frequencies can operate reliably on other frequencies in the event that one becomes unusable due to interference. The more simultaneous frequencies the repeater supports, the more it can tolerate interference. For example, a four-radio digital repeater can continue to operate even if three of those radios become unusable. The following diagram illustrates how well a Rajant Kinetic Mesh network can tolerate interference.



This diagram depicts a Rajant Kinetic Mesh mesh network with eight LX5 BreadCrumb nodes, each configured with four transceivers and four frequencies. The illustration shows three areas where interference exists. The first is shown on the 900 MHz band between nodes A and D and A and E. The second affects both the 900 MHz and 2.4 GHz bands between nodes D and G, and the third is on the 5 GHz band between nodes C and F. In each instance, more than one frequency is available over which data can be transmitted. The InstaMesh protocol detects the interference, avoids those links, and utilizes the multiple available frequencies.

Multi-transceiver, multi-band radios provide additional advantages, including:

- **Increased Maximum Throughput:** Typically, digital radios must wait for a packet to be fully received before retransmitting or forwarding it on the same frequency. As a result, the effective maximum throughput of the channel is reduced by half when operating in this manner. Our BreadCrumb multi-transceiver, multi-band radios can retransmit a packet on a different frequency than the one over which it was received. By using two different data streams, the packet can travel at the maximum throughput rate, rather than half the rate.
- **Reduced Latency:** If a packet is part of a data stream being retransmitted on a different frequency than the one over which it was received, it does not have to wait for a break in the original transmission. Instead, the packet can be forwarded with significantly less delay than a packet that must be retransmitted on the same frequency. Using two frequencies reduces latency considerably.
- **Reduced Jitter:** When a digital radio relies on a clear channel assessment (CCA) to schedule transmissions, which is typically the case with any half-duplex system, the exact timing of transmissions can vary significantly. The degree of variation increases geometrically based on the number of transmitters using the same frequency. Spreading the number of possible transmissions over multiple frequencies helps to mitigate this effect and, thereby, reduces jitter.

For industrial organizations, multi-transceiver, multi-band radios can provide continuous, on-the-move access to critical applications and information, while providing them the confidence that their data is complete and accurate.



Summary

Detecting interference can be challenging because it can occur sporadically, and its incidence patterns often change over time. To overcome interference effectively, you need a wireless infrastructure that has a high tolerance for interference and can mitigate its negative effects while ensuring the continuous, reliable, high-performance connectivity needed to achieve your specific communication objectives.

At Rajant, we have more than a decade of experience working with industrial organizations that have experienced significant interference issues before deploying a Kinetic Mesh network. After deploying Rajant private wireless networks with multi-transceiver, multi-band nodes, their networks met and typically exceeded their expectations.

Although you cannot completely eliminate interference, you can circumvent it with our multi-transceiver, multi-band BreadCrumb nodes.

About Rajant Corporation

Rajant Corporation is the exclusive provider of private wireless networks powered by patented Kinetic Mesh technology, BreadCrumb® network nodes, and InstaMesh® networking software. With Rajant, customers can rapidly deploy a highly adaptable and scalable network that leverages the power of real-time data to deliver on-demand, critical business intelligence from the field. Rajant BreadCrumbs can seamlessly integrate with any Wi-Fi or Ethernet-connected device to deliver low-latency, high-throughput data, voice and video applications across the meshed, self-healing network. With the ability to take private network applications and data everywhere, Rajant networks are used across a broad array of industries, including military, industrial, transportation, utilities, telecommunications, and all levels of governments. **For more information, visit www.rajant.com.**

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“We were not able to trust all of the data we collected until we implemented the Rajant network.”

— James Stewart, Technical Services Manager,
ASARCO Ray Mine

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