RADiS™ Multi-core RF Processor

Layer Zero of the IoT

Scale the IoT with longer battery life and 10X reliability

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RADiS™(denoted from RF Adaptive Diversity in Synchronized networks) multi-core processor has been referred to by some as layer zero of the IoT. Obviously the OSI model of modern networks starts at layer 1 with the physical layer and does not contain a layer 0. The statement refers to the fact that the IoT and particularly the Industrial IoT (IIoT) needs a new low power, high reliability wireless foundation that solves several imminent challenges in order to scale.

At the heart of the solution is a RADiS RF front end that is proven to extend performance by at least 10dB while remaining protocol agnostic. The solution works for any protocol operating under any spectrum. Backwards compatibility means RADiS wireless systems can be deployed in a grow-as-you-go manner. There is no need to overhaul the network with entirely new elements. Both greenfield and brownfield applications will benefit.

When was the last time a new technology bought you 10dB of link margin without changing the protocol, modulation or spectrum? Is a 10X improvement really possible? Yes, we measured it….

Before we get into all that, let's talk about some challenges relating to wireless and the benefit of more dB. Raise your hand if you've experienced a dropped call. Or if your apartment or office has a dead spot that you avoid when you're on a call. Or the frustration associated with a consistently garbled voice call. Or the mysterious connect, disconnect, connect cycle that many of our Bluetooth devices impose on us?

The reality is that for you and me, none of those maladies have stopped wireless from being deployed usefully. You and I can still communicate with our friends and coworkers. We can still email, browse the internet and stream video. Dropped calls and unreliable connections are minor speed bumps in our daily lives. We are grateful for the ability to make our calls, browse the internet and email our colleagues on the run.

For a machine, on the other hand, a dropped message, intermittent connection or altogether network failure can stop its function literally in its tracks. For example, drones now have failsafe systems that force them to return to base when they lose the wireless link. The mission is over. Machines do not have the same agency as humans. Moving out of a dead spot, waiting for a better connection or simply retransmitting the message may not be an option.

Given that machines depend more on wireless than humans, our approach to IoT connectivity must account for a higher level of reliability in order to scale. Although today's IoT seems to be operating fine, challenges loom as the density of devices increase.

Increased crowding in the global 2.4GHz band already is known to cause problems. Other bands such as sub-GHz and 5GHz will soon follow. Such coexistence issues will only worsen and must be solved before the IoT can expand to its full potential.

Scaling the IoT demands installing and deploying remote sensors, autonomous and roamable machines, drones, sustainability meters and new safety systems further and in more hostile locations. The low hanging fruit of easy deployments will diminish as mobility and complex environments compound to challenge wireless connectivity.

Does more dB achieved by RADiS functionality solve the challenges? We put it to the test addressing one of the toughest industry challenges–wireless coexistence in the 2.4GHz band.

Test Case: Coexistence with Wi-Fi in the 2.4GHz band

The 2.4GHz band has special appeal because it delivers broadband capabilities in a set of frequencies that devices can use globally without a spectrum license. Users can deploy a network using common globally available hardware and zero monthly subscription cost. The clear benefit is global interoperability within protocols and lowest possible cost. That is the recipe for a successful IoT deployment.

However, there is no control of interference from adjacent networks. A Wi-Fi network and an IEEE802.15.4 network operating in close proximity emit RF into the same airspace and 2.4GHz band in an electromagnetic game of chicken. Most protocols are designed to back off when they perceive other protocols operating in the same band. But this back-off mechanism is not perfect and the signals often collide in the air. So who wins? Usually they both lose but the signal with wider bandwidth and higher output power typically prevails.

In our example, that's Wi-Fi since IEEE802.15.4 operates with lower RF output power, narrower channels and occupies less percentage of airtime. In real life deployments, unmanaged shared airspace between the two protocols will typically impact IEEE802.15.4 causing lost packets and retransmissions which can delay the data and drain battery life over the long run. Solving this problem at the system level and regaining packet throughput and battery life involves careful coordination and planning at the plant level. The challenges compound as both networks compete for additional airspace as the demands on each network grows. It's easy to see how limiting this real life scenario will become in IoT deployments.

Enter the RADiS wireless physical layer solution. A RADiS multi-core RF processor gangs together multiple radios, operates them in unison, post processes the data received to discern environmental RF effects and adaptively controls the RF to overcome RF aggressors in the environment. The process effectively rebuilds the pristine signal and attenuates harsh environmental effects thereby increasing link margin or link strength. Details of RADiS patented operation are beyond the scope of this whitepaper. Rather we are introducing compelling test results that show benefits such as increased battery life while operating in harsh environments.

RADiS functionality can be applied to any protocol. Operation is independent of spectrum or band. For this test, Spearix developed an IEEE802.15.4 test design (DUT). The TX and RX DUTs employed a 4X or 4th order RADiS functionality, meaning four radio front ends on each side with a single antenna each. The test will transmit 100 identical 40byte packets at 250kbps data rate over each of the four radios, creating a quad redundancy.

IEEE802.15.4 is the radio standard behind WirelessHART, ISA100, Thread and Zigbee. It also shares many physical layer traits with Bluetooth. Therefore, the results of the test apply across a broad set of high reliability and consumer IoT applications.

Since real life deployments have many uncontrolled variables, Spearix set up a repeatable test bench. The goal of saturating the airspace with Wi-Fi traffic was accomplished using several devices running an application called iPerf. iPerf generates and transmits data over a controlled configuration that allows fixing the channel and data rate. .

Three independent iPerf links will occupy about 80 percent of the available 2.4GHz spectrum. Each link operates in a different channel. In our test we set up Wi-Fi channels 1, 6 and 11 delivering data at a rate of 56Mbps. Figure 1 demonstrates the major elements of the test, showing one half of each the Wi-Fi iPerf links. The DUT RADiS transmitter and the other half of each iPerf Wi-Fi link (not shown) were distant. Three iPerf Wi-Fi portable devices were placed in proximity to the DUT RADiS receiver such that received packet errors can be induced.

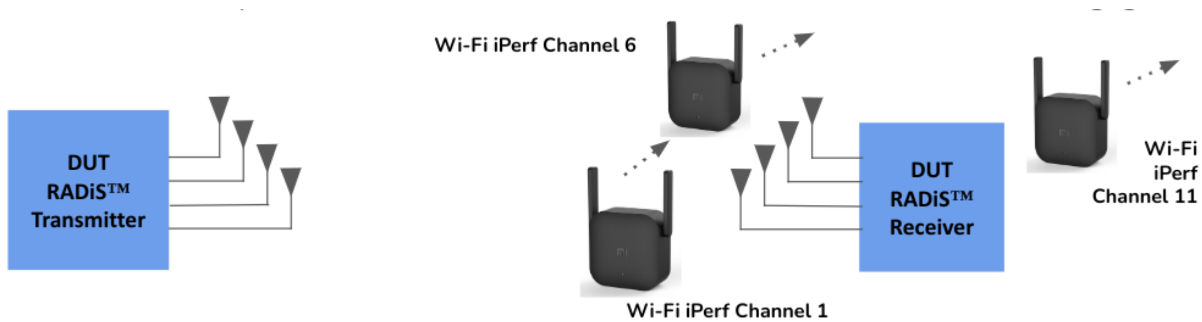

Figure 1. Wi-Fi coexistence device setup.

The procedure begins with baselining the Wi-Fi interference. While the TX and RX operate with RADiS functionality off, meaning a single TX and RX connection without the benefit of the extra radios, the iPerf Wi-Fi devices are positioned close and closer to the RX DUT until the link fails to zero packet throughput or 100% packet error rate (PER).

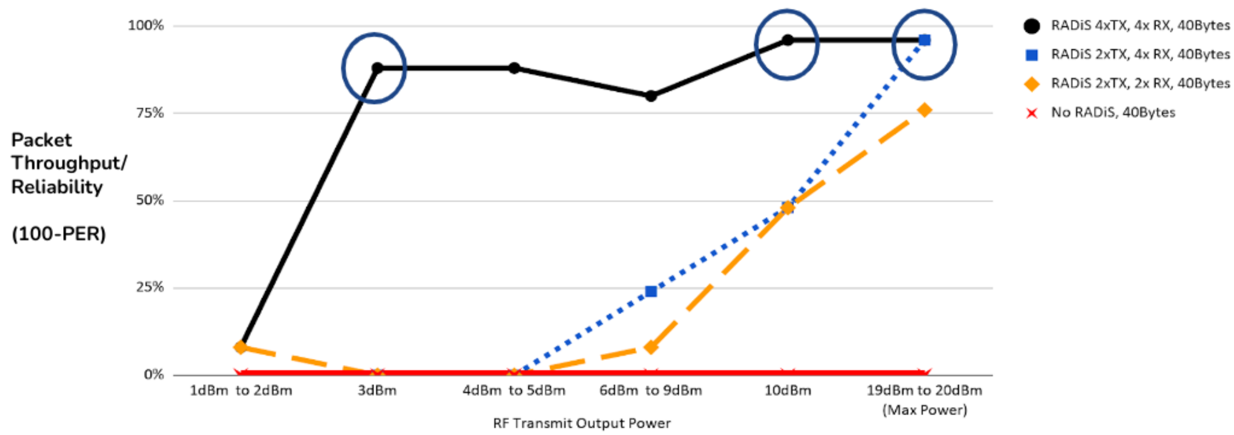

Figure 2. Packet throughput vs RF output power of Wi-Fi coexistence test results shows wireless link improving from 0% to 80% and 96% packet throughput with full RADiS™ functionality enabled.

Figure 2 shows dramatic results as RADiS functionality activates. The red trace is the baseline knocked down to zero packet throughput and remains at zero as the RF output power is swept from 1dBm to 20dBm. Clearly with standard radio systems, a strong enough RF aggressor cannot be overcome by boosting RF output power. The packet throughput is completely insensitive to more RF output power and echoes results seen anecdotally in the field. Many engineers see that maxing output the RF output power doesn't always heal the link.

In contrast, as you active RADiS functionality, the packet throughput becomes sensitive to output power. A 2X or second order RADiS activation shown in the yellow trace begins to recover packet throughput starting at 6dBm RF output power. At max power, the throughput hits 75%.

With full 4X or fourth order RADiS functionality, the packet throughput shoots to 80% at 3dBm, an astonishing 1/50th of the max RF output power. Although four RF cores are operating, the overall RF output power required drops to 1/12th. This is a considerable improvement in power consumption given that the alternative delivers 0% packet throughput.

Increasing RF power further, 96% packet throughput is achievable. The same environmental conditions that baseline at 0% without RADiS functionality even at full power, can be overcome employing RADiS functionality while consuming half the overall power.

Substantially lower power consumption with higher reliability in the presence of high interference: is this not what the IoT demands?

The plot in figure 2 clearly demonstrates that multi-core operation presents geometric gains beyond what is obvious. Can we quantify the benefit?

When increasing from a baseline of zero packet throughput to 96%, the gain cannot be quantized because it's calculates to be infinite. Quantizing requires a non-zero baseline. In subsequent tests, the iPerf Wi-Fi test was situated to produce a baseline of 50% packet throughput. A higher resolution is necessary so instead of 100 packets, 1000 packets were transmitted and RADiS functionality was activated. Activating RADiS functionality in that case resulted in only a single packet lost, yielding a 99.9% throughput. Based on Shannon's capacity theorem, that corresponds to 10dB more signal to noise compared to baseline. Spearix measured an equivalent 10X increase in signal to noise ratio by activating a 4th order RADiS multi-core RF processor.

Results: 10X reliability, 3X range, 9X area coverage, longer battery life

RF engineers should intuit that a 10dB gain has multiple ramifications. Following Shannon's theorem, 10dB can be used to increase capacity. However, it can also be used to increase range. And in fact, our tests show that a 4th order RADiS solution increases range by approximately 3X, all things being equal. The commercial impact compounds when you consider that a 3X increased radius of coverage translates to a 9X increased area of coverage. One gateway can cover 9X more ground and density, reducing the need for repeaters and boosting its effective value in IoT applications.

In 3D environments, like factories, refineries, processing plants and oil rigs, it translates up to 27X more volume coverage. It's easy to see how 10dB can help a network scale.

Let's consider battery life. In our example, 50% packet throughput means every other packet needs to be retransmitted when it fails. And 50% of retransmissions also fail. An 8th of all packets need more than three or more retransmissions. The compounding effect lowers battery life and increases latency. The culprit limiting battery life becomes poor reliability, not instantaneous peak operating power consumption. In contrast, the RADiS solution cuts through the noise almost every time, reducing retransmissions and latency while extending battery life.

Conclusion: 10X reliability for battery powered IoT devices

Is RADiS multi-core RF processor the layer zero of the IoT? We know there is no layer zero. However, with crowding, coexistence and harsh environmental challenges coming, wireless will soon need a physical layer enhancement. Being protocol and spectrum agnostic and providing other benefits not discussed such as environmental visibility, RADiS solutions could present the low power, high reliability wireless connectivity needed to scale the IoT in a valuable and reliable manner.