White paper

Interleaved MIMO: Near-full MIMO performance, nearly half the costs

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Introduction

The increasing demands on today's indoor distributed antenna system (DAS) networks are pushing network operators to consider solutions capable of providing exponentially higher data rates. As a result, many network operators are exploring the use of multiple-in, multiple-out (MIMO) transmission schemes in a DAS environment.

Until recently, achieving the higher data rates possible with MIMO came with a high CapEx investment, forcing many DAS network operators to choose between wireless performance and bottom-line profitability. However, successful testing of an alternative scheme—interleaved MIMO—enables operators to realize near-full MIMO performance for about half the cost.

Colocated MIMO: High performance at a high cost

A traditional colocated 2x2 MIMO DAS, shown in Figure 1, is deployed using two radiating points colocated in the same general location. By using the spatial dimension of a communications link, MIMO systems can achieve significantly higher data rates than traditional single-input, single-output (SISO) channels.[1]

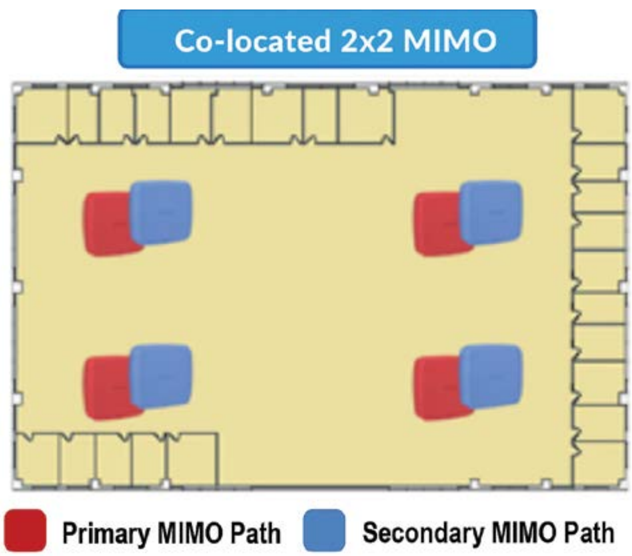

Figure 1

A 2x2 MIMO system produces two spatial streams, effectively doubling the maximum data rate of a traditional 1x1 SISO communications channel. This is illustrated in Figure 2, where the data rate—near the user access point—in a colocated 2x2 MIMO DAS is twice that of a SISO DAS. Due to a reduction in the SINR of the LTE signal, the data rate decreases as the user moves away from the access points.

While the performance benefits of a colocated MIMO DAS are attractive, the cost to upgrade can be prohibitive. In DAS systems involving a single transmit antenna and multiple receive antennas, upgrading to colocated MIMO means nearly doubling the amount of equipment needed. When the upgrade involves LTE, the total cost is even higher. Because the LTE e-Node B supports 2x2 MIMO by default, its second antenna branch goes unused, as it is simply terminated on a 50-ohm load. This results in wasted space at the DAS headend and wasted baseband capacity in the e-Node B..

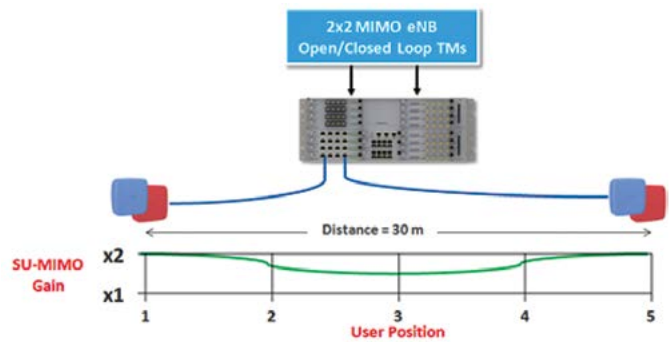

Figure 2

Interleaved MIMO DAS: A lot more performance for a little more money

An alternative to colocated MIMO is interleaved MIMO, in which the access points are separated by a relatively large distance (Figure 3) and the branch signals from each access point are interleaved across the coverage area. This provides excellent radio coverage and minimizes power imbalances among the RAUs. The result is lower fading, higher capacity and increased data rates.

Interleaved MIMO, also known as I-MIMO, has been shown to provide near-full MIMO performance. But, because it requires no additional cabling or equipment, there is no cost to upgrade.

I-MIMO in a DAS environment has been explored on and off for a number of years, but has remained more of a concept than a practical solution. The key obstacle to its implementation is that LTE 3GPP specifications do not address the placement of the primary and secondary synchronization signals (PSS/SSS) on both MIMO antenna branches. Both signals are critical in order for the mobile device to identify and communicate with the cells transmitting within the area.

The primary synchronization signal (PSS) provides the mobile device with the symbol timing and information about the physical identity of the cell. The secondary synchronization signal contains the frame timing, transmission mode (FDD or TDD), and the cyclic prefix duration (normal or extended). Without these signals being radiated from every antenna point, the mobile device may not connect to the network.

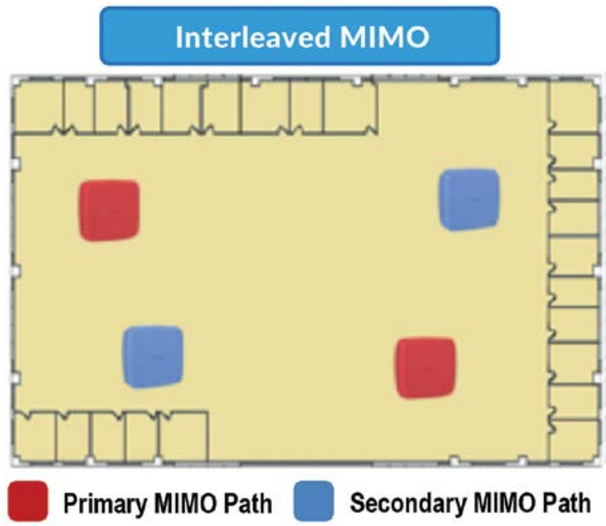

Figure 3

Another obstacle to successfully deploying I-MIMO in a DAS environment involves the cell-specific reference signals (CRS) and the reference signal received power (RSRP). These are specified by 3GPP based upon a colocated MIMO configuration; specifically, in 2x2 MIMO, the PSS and SSS should be radiated from all antenna locations. This specification limits I-MIMO deployments in which there are large separations between the primary and secondary signal paths.

Recently, engineers at CommScope developed—and have since patented—a method of placing the PSS/SSS and the CRS signals on both antenna paths, allowing interleaved MIMO to be successfully deployed. The solution essentially creates a matrix in the software that enables the PSS/SSS signals to be placed in both MIMO data streams. Engineers then incorporated these capabilities into the company's existing ION-E™, CommScope's unified platform for indoor wireless.

Comparing performance of I-MIMO, colocated MIMO and SIMO

To compare the I-MIMO solution against SIMO and colocated MIMO, the three technologies were tested in the lab of a major European carrier. The test setup was designed to simulate multiple wireless environments. Figure 4 shows how each of the three performed during line of sight (LoS) and non-line of sight (non-LoS) walk tests.

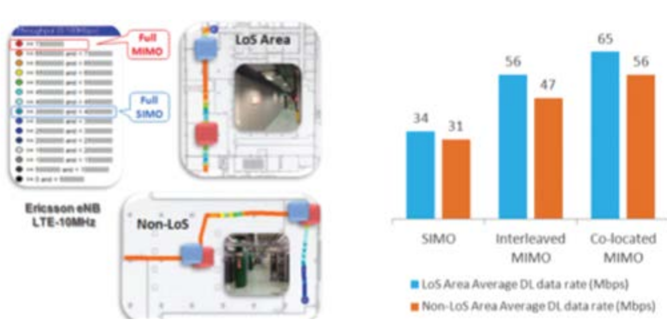

Figure 4: Walk test results

The summary bar charts in Figure 4 confirm the commonly held belief that colocated MIMO delivers approximately twice the data rate of SIMO. Of special interest is how the interleaved MIMO compared to SIMO and colocated MIMO. In LoS testing, I-MIMO's measured downlink data rate of 56 Mbps was 65 percent greater than SIMO and just 14 percent lower than colocated full MIMO. Non-LoS tests showed I-MIMO delivered a 52 percent increase in data rate over SIMO and was only 16 percent below colocated MIMO.

It is also interesting to note how the performance of the I-MIMO changes as the user moves farther away from the access point. Figure 5 shows that, when the user is at or near the access point, the data rate is approximately the same as a SIMO system. The data rate increases as the user moves away from one access point and closer to another. This is the opposite effect of colocated MIMO, noted in Figure 2.

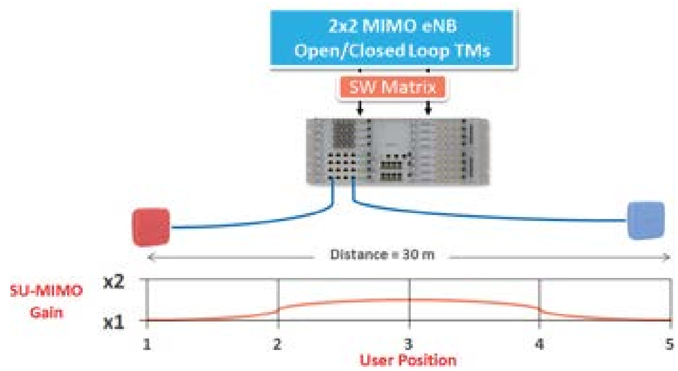

Figure 5: Interleaved single-user MIMO

While colocated MIMO provides incrementally higher data rates than I-MIMO, it remains largely cost prohibitive for all but the largest facilities and venues. As noted earlier, for a colocated 2x2 MIMO deployment, each access point location requires two remote access units (RAUs) as well as all-new cabling. The deployment cost grows rapidly as MIMO order increases, as each antenna requires a closely spaced, but isolated, RF chain and computational complexity grows dramatically. The more complex the device, the higher the per-unit cost.

There are higher costs on the OpEx side as well. Having more RAUs translates into greater power requirements and an increase in ongoing maintenance and repair costs. Colocated MIMO comes with increased soft costs also, including the physical space required to install additional access points.

Upgrading to an interleaved MIMO DAS, however, involves simply updating the software at no cost. No extra cabling or hardware is required. Typically, the cost difference between upgrading to interleaved MIMO and colocated MIMO is approximately 55 percent.

Achieving success with I-MIMO

The development, computer modeling and field testing of I-MIMO using ION-E have identified two elements that are critical for success.

1. Signal-to-interference-plus-noise ratio (SINR) should be greater than 20 dB to guarantee that the channel can support a higher data rate. Any design that meets the typical targeted key performance indicators (KPIs) will be sufficient to support this requirement.

2. Assuming a 2x2 MIMO configuration, the delta between signal levels from the two antenna paths should be less than 12 dB to keep the two data streams balanced. Figure 6 shows that, in an open space environment, when access points are spaced 30 meters apart, the 12 dB delta is reached at approximately 5 meters from the access points. In other words, the I-MIMO solution provides excellent balance between the data streams for over two-thirds of the coverage area. Note that there are no special design rules or AP spacing requirements for implementing an interleaved MIMO network. A standard SIMO design that meets the targeted KPIs is sufficient.

When both of these criteria were met, interleaved MIMO provided the same performance as colocated MIMO.

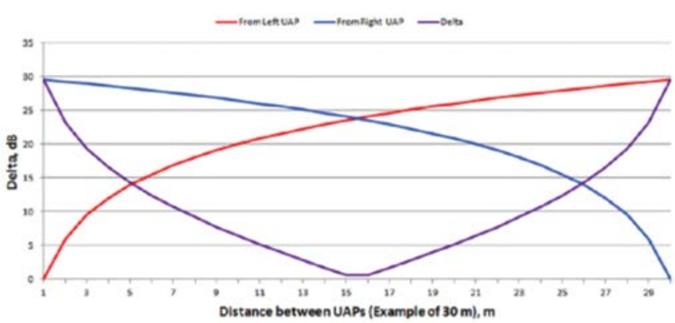

Figure 6

Moving to full MIMO and beyond

MIMO, in addition to carrier aggregation, has been singled out as a key transmission technique necessary for meeting network capacity demands—now and in the immediate future. As more indoor wireless networks look to support LTE-Advanced (LTE-A), MIMO is one of the only technologies able to provide a spectral efficiency of 30 bit/s/Hz, as required by the standard.[2] What's more, an in-building DAS environment is ideal for MIMO because it provides very good signal-to-noise ratio and a rich scattering environment.

For facility IT managers, the major challenge is how to migrate to MIMO in a way that makes financial sense. This means building a stronger business case for MIMO and developing a practical path to get there. With the demonstrated ability to achieve near-full MIMO performance at just 55 percent of the cost, interleaved MIMO provides a cost-effective stepping stone to full MIMO and beyond.

End notes

[1] Understanding Benefits of MIMO Technology; Microwaves & RF; May 20, 2009

[2] TS 36.211 V11.1.0, "Physical channels and modulation (Release 11)"; IEEE 3GPP; 2012.

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