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MU-MIMO

More capacity, without additional spectrum

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Introducing MU-MIMO

MU-MIMO is a 3GPP defined technique that when deployed using a Telrad 4x4 eNodeB can increase sector capacity between 40-70%. The capacity improvements are achieved **without additional spectrum**, new base station hardware, or a truck roll to the site. The feature can be deployed over-the-air in minutes. The economic impact is impressive, increasing sector market share at a lower cost/sub. For example, an operator with a 50-subscriber sector can implement MU-MIMO to add 20-35 additional subscribers (for a total of 70-85 subscribers). Using an average of $60/subscriber per month, monthly revenue increases to between $1,200 and $2,100.

This white paper explores the benefits of MU-MIMO, using beamforming and spatial multiplexing techniques in a fixed LTE network. In addition, this document discusses what performance improvements one can expect by implementing MU-MIMO and best practices for deployment.

MU-MIMO Software:

Telrad's MU-MIMO feature combines **beamforming and spatial multiplexing techniques**, which, together, bring a significant increase to overall sector capacity in the range of 40% to 70%. While the theoretical maximum is 100%, the practical maximum is 70% due to a requirement for calibration overhead. The feature is enabled through software (Telrad E-UTRAN Release 7.2), and is supported on the current eNodeB hardware available from Telrad, e.g. BreezeCOMPACT and BreezeU-100 software defined radio platforms.

How it works:

MU-MIMO (Multi-User MIMO) pairs user equipment (UE) with the same frequency-time resource, allocated simultaneously, by applying dynamic precoder weights (amplitude and phase) on the signal.

This technique enables beamforming to reach each of two, dynamically paired, subscriber (UE) device's assigned data layers and to null unassigned data layers. This keeps the paired-devices from interfering with each other even though they are using the same frequency-time resource within the sector. The two devices are separated by individual beams as opposed to frequency, enabling a 4Tx/4Rx base-station to serve both devices independently, with up to two data streams per device. Furthermore, the scheduler can allocate multiple user-pair combinations, on different parts of the channel, serving several MU-MIMO user-pairs per TTI (Transmit Time Interval), further improving the system spectral efficiency.

Dual Layer Beamforming TM8:

Transmit Mode 8 (TM8) supports a UE specific RS (reference signal), which allows for more flexible beamforming to occur. The benefit of which is complete suppression of any interference between paired devices. This technique is known as block-diagonal zero-forcing (BD-ZF). The reciprocity of the channel on a TDD system allows for an accurate channel learning process, which is based on uplink sounding and adaptive base station antenna array calibration. TM8 is defined by 3GPP standards, meaning the technique is fully standards-based and supported by all CPE types within Telrad's portfolio. There are no proprietary dependencies such as those that exist in Wi-Fi-based technologies.

Beamforming:

The beamforming concept is to transmit the same signal, through multiple antennas, to a specific UE, while properly appropriating the signal on each antenna. In other words, the base station (eNodeB) creates a focused, narrow frequency beam (like a flashlight) that targets a specific UE. Beamforming coherently combines the amplitude of signals, from all antennas on the UE side, i.e. the transmitted signals combine in the air and reach the targeted UE in the same phase. The coherent combining of the amplitudes results in an increase of up to 6dB in power on each antenna element in a 4TX system (using +45/-45 polarization with X-X antenna).

For UEs experiencing low Signal to Noise (SNR), the increased receive power, achieved by beamforming, increases the MCS (Modulation and Coding Scheme) level, ultimately improving spectral efficiency and therefore bandwidth to the end-user.

Note that, as with TM8, beamforming is dedicated to a specific UE, therefore it is applied only on the data QAMs and on the UE-RS (UE-specific reference signals), but not on the common CS-RS (cell-specific RS). This means the beamforming power gain will not be reflected on the reported DL SNR (as UE SNR measurements are based only on the CS-RS). However, the UE will achieve a higher MCS as a result of the gains resulting in better performance.

Baseband Unit Scheduler Impact:

The scheduler selects the device-pair according to their spectral-efficiency (SE) score, maximum aggregate SE limit, and minimum QoS (Quality of Service) threshold. Based on the criteria, the scheduler decides if antenna energy is to be split between several devices with ***MU-MIMO*** precoding weights, or to focus all the energy toward a single UE with a proper ***beamforming*** precoding weight. Aggregate spectral efficiency, in the case of MU-MIMO, is impacted by a power penalty of 3dB, for each UE, based on the total number of antennae power splits (between device-pairs) and precoder power gain criteria. The precoder power gain, derived from the channel correlation between the devices, describes the ability to transmit separate beams towards both devices (beamforming to one UE while nulling to the other UE), the performance of which is determined by the geographical positions of the UEs, i.e. separation between UEs.

For devices with uncorrelated channels, the precoder power may be as high as a +6dB beamforming power gain per UE.

For devices with highly correlated channels (UEs geographically located adjacent to each other), the precoder power penalty may be too high to establish MU-MIMO, thus the scheduler may opt to search for another pair of devices, in order to maximize the aggregate spectral-efficiency score. The scheduler will couple most devices with MU-MIMO since the reduced receive power (if any) to each UE is often tolerable and not dramatic, resulting in a loss of some spectral efficiency for each UE, but achieving a much higher aggregate spectral efficiency with both. In cases where UEs have high signal-to-noise ratios (SNR) and uncorrelated channels, the scheduler may serve them simultaneously, coupled as MU-MIMO, achieving high aggregate spectral efficiency and high throughput over the same bandwidth. In some cases, they will still be allocated with their maximum MCS. For a UE with low downlink (DL) SNR, the scheduler may opt to apply Single User (SU-MIMO) beamforming (serving a single UE), thus the UE will benefit significantly from a 6dB beamforming gain, improving SNR, and, hence increasing throughput.

Correlated channels
No MU-MIMO
<6° horizontal separation

Uncorrelated pair
gets MU-MIMO = higher
aggregate spectral efficiency

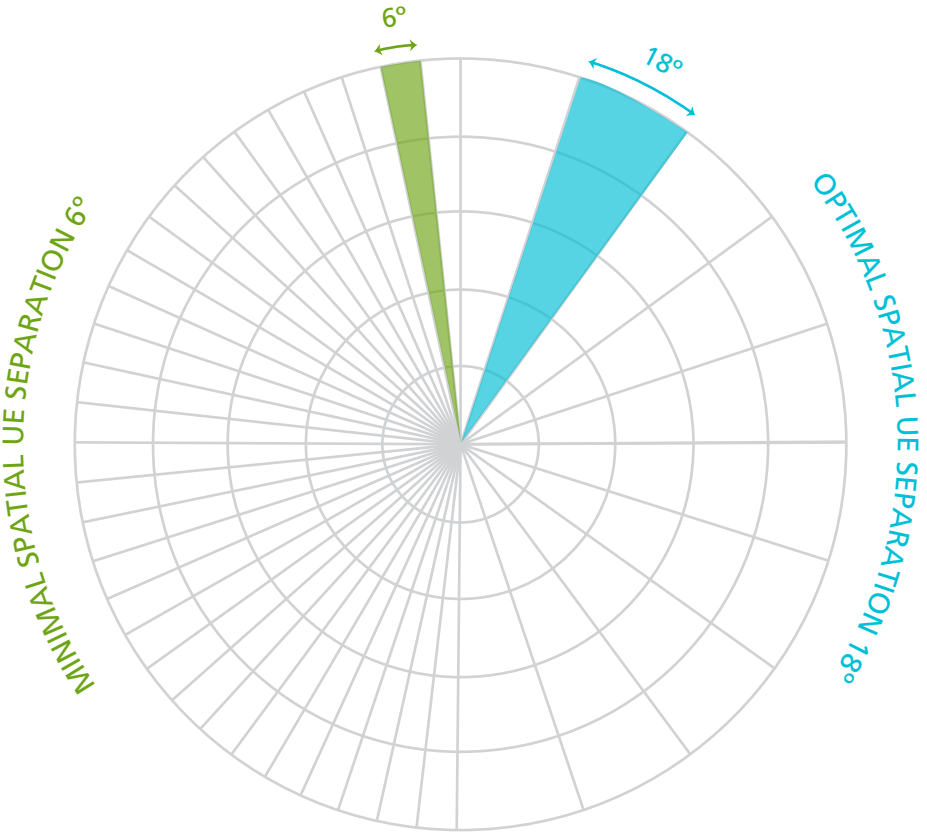
UE low downlink SNR
SU-MIMO +6dB gain per UE
with TM8 Beamforming

MU-MIMO Performance:

For a cell deployment with a relatively good group of high SNR devices, MU-MIMO will achieve a significant gain in the sector's aggregate throughput, more than 170% relative to an SU-MIMO TM3 2x2 case, where each of the paired devices maintains its maximal MCS. For low SNR devices (<8dB), the SU-MIMO will achieve a significant gain of more than 200% relative to the TM3 2x2, due to +6dB beamforming to a single user.

Implementing MU-MIMO:

MU-MIMO in the Telrad system is dynamic. The scheduler makes decisions based on KPI based algorithms. Once set up, the performance improvement for any UE in the sector is dynamically determined and implemented by the scheduler. On the UE side, using spatial separation of >6 degrees minimally and 18 degrees optimally, are key factors that determine whether the capacity benefits. In either case, Telrad can help maximize the performance of the feature.



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