Boost mobile networks using MIMO and DAS

MIMO significantly enhances network capacity and data throughput in LTE networks while conserving spectrum resources.

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As the wireless applications expand due to smart phones, tablet computers and a growing applications developer base, mobile operators are constantly searching for ways to deliver more capacity in their networks without using precious spectrum resources.
Multiple input/ multiple output (MIMO) technology is now gaining substantial momentum in wide area mobile wireless network architectures with the launch of LTE services. MIMO is a key technology that substantially improves network capacity and data throughput in LTE networks while conserving spectrum resources.
MIMO stands for "multi-input, multi-output." It made its first broad commercial appearance in 802.11n systems. Input refers to the number of transmitter antennas and output refers to the number of receiver antennas (**figure 1**). SISO mode (single input, single output) is the classical mode of communication architecture, where there is one antenna transmitting and one antenna receiving.

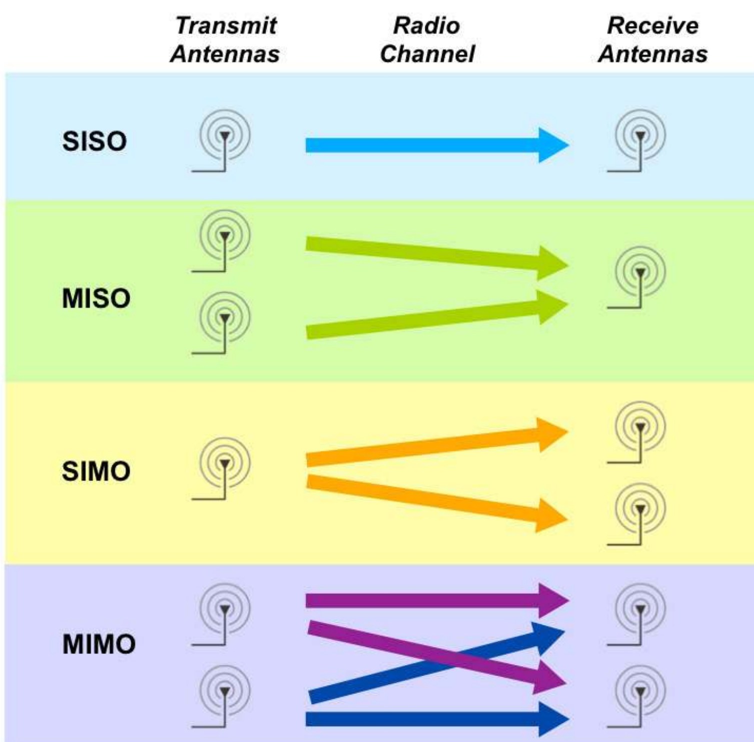

Figure 1: SISO and MIMO modes.

MIMO uses multiple transmit antennas and multiple receive antennas. Multi-antenna configurations have been around for years, but with advances in signal processing and silicon, MIMO is now economically possible in many small form factor devices such as handsets and data cards. All practical LTE devices support MIMO, as required by the 3GPP standard. While initial LTE networks use downlink 2x2 MIMO (where there are two transmit antennas and two receive antennas), future LTE systems will use downlink 4x2 or even 4x4 MIMO and even higher dimensions of antenna configurations. LTE Advanced systems will have the nominal ability to use up to 8x8 MIMO downlink antenna configurations and up to 4x4 MIMO in the uplink, although actual device implementations supporting these modes may take some years to come to market.

For MIMO to work, a rich scattering environment (with many different paths between transmitter and receiver) as

well as a high signal-to-noise ratio (SNR) are needed. Rather than being a detriment to network performance, a multi-path environment is actually exploited by MIMO processing to increase the capacity or the coverage of the network. The key is that each path must be independent and look different to the receiver. The differences in the multi-path are used to create orthogonal communication channels analogous to the orthogonal spreading codes in CDMA-based systems. In addition to being required for the higher orders of modulation, such as 16-QAM and 64-QAM, a high signal-to-noise ratio is also required to properly exploit the MIMO wireless channel, and to allow MIMO systems to algorithmically separate the multiple spatial transmission paths, which overlap one another in frequency and time.
An in-building Distributed Antenna System (DAS) is ideal for MIMO because it provides very good SNR, and in-building environments provide a rich scattering environment.

MIMO types
There are two major categories of MIMO – spatial diversity, in which the same data is transmitted over each of the multiple paths, and spatial multiplexing, in which each of the paths carries different data. In 2x2 MIMO with spatial diversity, for example, each of the two antennas is essentially transmitting and receiving the same data although the data is coded differently and each channel is separable. This mode is primarily used to improve signal quality or to increase the coverage area. In 2x2 MIMO with spatial multiplexing, a different stream of data is transmitted over each of the two sub-channels, and this can increase throughput by a factor of up to 2x over the single sub-channel throughput as shown in **figure 2**, depending on the SNR of each sub-stream, and the base station rate adaptation procedure.

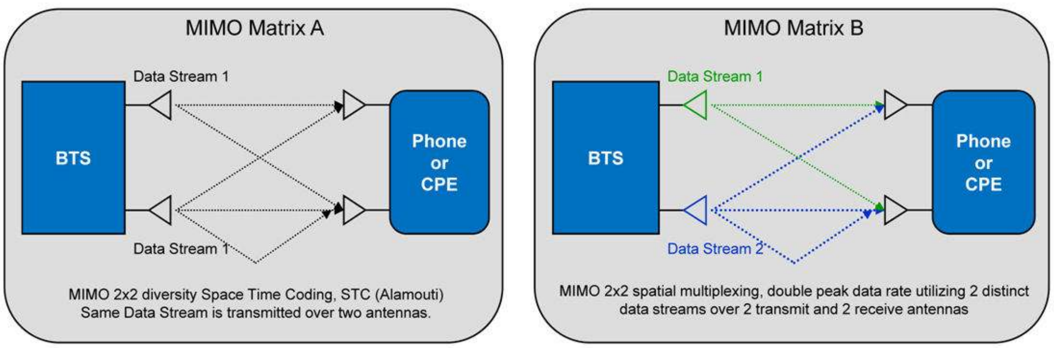

Figure 2: Spatial diversity versus spatial multiplexing.

Spatial multiplexing is the mode that really takes advantage of the capacity improvement capabilities of MIMO. Provided the MIMO channel quality (i.e. SNR and sub-stream separation) is sufficiently good, the system throughput can be increased linearly with the number of transmit antennas without using any additional spectrum resources. Given the scarcity and cost of the wireless operator's spectrum, improving the spectral efficiency is a critical goal for improving the overall financial operating margins for the mobile operator.
It is important to note that commercial MIMO systems switch dynamically between SISO, MIMO diversity, and MIMO multiplexing modes, depending on a variety of factors including the channel environment and signal quality. For example, if the signal quality is very high the system uses spatial multiplexing, and if not, it automatically switches to spatial diversity mode or even to SISO mode.

MIMO challenges
The key challenge of using MIMO is that it can require more infrastructure and is therefore more expensive than using SISO. DAS products use remote amplifier units (RAUs) to broadcast signals. Contemporary advanced RAUs can usually support one or two antennas and one or more frequency bands. Thus, to do MIMO on, say, two frequency bands (i.e., 700MHz and 2300MHz) while providing SISO service on other bands (e.g. 900MHz, 2100MHz) can require a second RAU and a second antenna to provide MIMO service on each band.
In some deployments, such as low traffic areas, the operator requirement is to focus initially on providing LTE coverage over as wide an area as possible, without emphasis on MIMO, so spending extra money to deploy MIMO in DAS systems is not preferred. However, MIMO is often required for high-traffic areas such as sports arenas, convention centres, and airports, and MIMO will be deployed in these venues because it is required to deliver the necessary capacity.
In addition, DAS vendors are working hard to reduce the overall cost of implementing MIMO, largely by increasing the capacity of RAUs so they can handle more frequency bands and more antennas.
MIMO alternatives
MIMO increases spectral efficiency because it allows the mobile operator to use two radios in the same frequency band to double the network throughput over the DAS. The alternative is to use SISO mode and double the number of

radios in the system. However, this requires the mobile operator to use two different frequencies, depleting precious frequency resources. There is a new 3GPP LTE Advanced feature called carrier aggregation that uses multiple RF channels at different frequencies to transmit data simultaneously to a user. This is similar in concept to MIMO except that MIMO uses the same RF channel instead of multiple RF channels. The benefit of carrier aggregation is that it does not rely on the multi-path environment and should provide more consistent throughput, but at the cost of more spectrum.

Another alternative is to increase the density of the modulation scheme (i.e. higher order modulation). Most of the cellular wireless systems are using at most 64-QAM modulation with coding. The throughput could be increased using a higher order modulation such as 128-QAM or 256-QAM, but this would require a much cleaner channel (i.e. substantially higher SNR and less fading). In addition, the higher throughput would be limited to a smaller area surrounding the antenna.

MIMO rollouts

Over the next five years or so, operators will deploy MIMO spatial multiplexing mode first in high-traffic areas, typically large public venues such as airports, arenas, and stadiums, where obtaining maximum capacity in the network is the primary concern. Low-volume sites such as small enterprises won't necessarily use MIMO. However, SISO and MIMO may be combined in certain sites where user density varies.

In a hotel, for example, the lower floors (public areas) of the hotel will be MIMO while the upper floors (guest rooms) will use SISO. As traffic increases in the guest rooms over time, the SISO layers in a site will be upgraded to MIMO. Geometric annual growth in traffic dictates that SISO implementations will eventually be migrated to MIMO. In addition, MIMO will initially be used to carry LTE traffic only, but over time even the legacy CDMA bands will migrate to LTE and therefore to MIMO because of the need for more capacity in the network. In short, there will be selective deployments of MIMO initially, but MIMO will spread over the next five years to supporting all bands and all significant traffic areas.

MIMO improves signal quality with MIMO spatial diversity, or throughput with MIMO spatial multiplexing. However, it is the MIMO spatial multiplexing mode that has created the latest buzz in the wide area mobile wireless industry as it delivers significantly higher throughput for mobile networks without the need for additional spectrum. At a time when 4G network bandwidth will be a key advantage in a service offering, MIMO makes sense as a way for mobile operators to address their capacity needs. Over time, MIMO will become the standard method of deploying mobile service infrastructure. ■

About the author

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