LTE Higher Data Throughput MIMO and Carrier Aggregation

MIMO and Carrier Aggregation (CA) are two technologies that improve network capacity, data throughput and the signal quality that is required by many of today's current use cases. Carrier Aggregation combines multiple carriers into one to increase the carrier bandwidth resulting in higher data rates. MIMO improves spectral efficiency using multiple antennas. Both subjects are discussed more fully in this document.

Improved data throughput in combination with signal quality are two essential requirements for modern cellular networks such as LTE-A and 5G. The original release of LTE in the 3GPP release 8 went some way to meeting these needs by supporting flexible bandwidths. It was release 10 and the utilisation of carrier aggregation and MIMO (Multiple-input-multiple-output) antennas which support high data rates in both the uplink and downlink channels that addressed the requirements more fully.

Minimised fading and supporting higher data throughput required a different type of modulation. Traditionally four types of modulation were used PSK (phase shift keying), FSK (frequency shift keying), ASK (amplitude shift keying) and QAM (Quadrature amplitude modulation). LTE needed a different approach and implemented OFDM (Orthogonal frequency division multiplexing) in the downlink and SC-FDMA (single carrier frequency division multiple access) in the uplink. OFDM is the basic signal format used in LTE giving the highest data rates and allowing for higher modulation techniques that the historical forms of modulation could not achieve. The OFDM carrier signal is the sum of several orthogonal sub-carriers with baseband data on each sub-carrier being independently modulated with QAM. This baseband signal is typically used to modulate a main RF carrier which can be referred to broadly as the channel.

OFDM

OFDM gives a method of encoding digital data transmission using many closely spaced sub-carriers modulated with a low-rate data stream. These signals are phased differently to reduce interference with other signals, eliminating fading and noise.

In LTE, OFDM has a maximum of 2048 different sub-carriers at 15kHz spacing, the 3GPP specification defines that all mobile devices have all 2048 sub-carriers however that is not the requirement for base stations with most currently offering 72, there will be a move towards 2048 as part of future infrastructure deployments.

QAM (Quadrature amplitude modulation) in LTE

There are four different modulations available QPSK / 16QAM / 64QAM / 256QAM by combining OFDM with the maximum number of carriers and utilising QAM256 you will achieve the highest data rate throughput. The LTE modulation is negotiated by the equipment depending upon the conditions. When there is a greater signal to noise ratio the higher order modulation QAM256 can be used and enhances data throughput. When lower signal to noise ratio is experienced, it makes it more demanding to extract the sub-carrier's modulation and lower modulation rates are used. The Lower the modulation rate the less bits per transmission can be achieved and therefore the less bandwidth is available to transmit data across the channel.

Single-carrier FDMA (SC-FDMA)

SC-FDMA is a frequency-division multiple access scheme. This scheme enables multiple users to communicate with a single base station. SC-FDMA is a popular method in uplink communications in LTE where lower peak-to-average power ratio (PAPR) benefits the mobile terminal in terms of transmit power efficiency and reduced cost of the power amplifier.

The performance gap between SC-FDMA and OFDMA is small but SC-FDMA's low PAPR means it is preferable in uplink transmission, where transmitter power efficiency is of paramount importance.

MIMO enhancing signal strength

MIMO (multiple input, multiple output) is an antenna technology used in wireless communications where the capacity and signal strength for both transmit and receive signals are enhanced through the use of multiple antennas improving spectral efficiency. This approach is adopted in LTE to further increase reliability and to improve the signal to noise ratio. Greater signal to noise ratios allows for higher modulation rates, improving data throughput by maximising the quadrature amplitude modulation being used. These types of antennas are available from Siretta in their MIMO antenna ranges.

MIMO Antennas to support higher data rates

3GPP release 13 specified MIMO modes for up to 16 transceivers at the base station, release 14 however is expected to allow as many as 64

bringing efficiency gains for downlink transmissions by utilising various antenna groups (2x2 through 4x4 up to 8x8 and so on to 64x2). As an example, you can expect a 2.5x gain in spectral efficiency using a 16x2 antenna configuration compared to a 2x2 antenna configuration, while 64x2 configuration shows a 3x gain.

Antenna Configuration	Spectral Efficiency (Compared with 2x2 array)
16x2	2.5x
64x2	3x

The gain available from a 64x2 configuration compared to 8x2 is 50 percent. Some transceiver configurations have four or eight columns of polarised antenna elements, while the 2x2 transceiver configuration has only one column of polarised antenna.

Aggregation of Antenna Signals

You can have up to 2048 sub-carriers so by combining more of these together, either in the same or different bands it is possible to increase the bandwidth available and, in this way, increase the capacity of the link.

The target figures for data throughput in the downlink channel is 1Gbps for 4G LTE. Even with advanced efficiency it is impossible to achieve this throughput. The only way to achieve the higher data rates is to also increase the overall bandwidth used. Various methods of Carrier aggregation can aid this:

Contiguous: The Intra-band contiguous carrier aggregation is the easiest form of LTE carrier aggregation to implement. Here the carriers are adjacent to each other. The aggregated channel can be considered as a single enlarged channel from the RF viewpoint, only one transceiver is required within the terminal, whereas more are required where the channels are not adjacent.

Non-contiguous: Non-contiguous intra-band carrier aggregation is more complicated. No longer can the multi-carrier signal be treated as a single signal and therefore two transceivers are required.

3GPP allows for up to five 20MHz carriers to be aggregated enabling a maximum bandwidth of 100MHz, although in practice the practical limit is two or three. These aggregated carriers can be transmitted in parallel to or from the same unit, thereby enabling a much higher throughput to be obtained.

Conclusions for Enhancing LTE and 5G Data Rates

LTE and 5G were designed to enable higher data rates, with multiple carriers, additional carrier aggregation and the ability to use multiple antenna paths for both transmit and receive which all go to producing a high-quality wireless link. The use of MIMO antennas combines signals and improves signal quality whilst enhancing data rates. Channel aggregation enhances bandwidth by combining multiple frequency carriers.

Historical limitations exist with some base stations only operating at the lower QAM, however, in time all cells will be upgraded to allow the highest rates. Geographic data and local population will influence this upgrade process.

When designing your application, it is possible to improve the data rates and operating performance of the entire system using MIMO in your design and Siretta can help you to select the best fit commercially for your end application from our extensive range of products and solutions.

Siretta understand the challenges faced and have developed their own Antenna selector tool www.siretta.com/products/antennas/antenna-selector/ to reduce time to market. Stretta's portfolio includes cellular modems & terminals, routers, cellular network analysers, RF antennas including MIMO antennas and solutions for WLAN, LoRa and Sigfox. Siretta offer RF cable assemblies and RF accessories. Frequencies are typically within the 75MHz – 5.8GHz range covering the HF, VHF, ISM, Cellular, GNSS frequencies.