A completely new power amplifier design is necessary to address RAN energy efficiency challenges

October 2024

Caroline Gabriel

The energy efficiency of mobile networks is an increasingly critical concern for telecoms operators, as they seek to reduce operating costs and improve sustainability. Amid climate catastrophes around the world, achieving net-zero emissions in mobile networks has become a key target, and over 85% of mobile network operators (MNOs) have committed to this goal. The power amplifier (PA) may not be the most top-of-mind component of the RAN, but improving its energy efficiency can significantly reduce its overall energy use and emissions.

RAN energy efficiency relies on a holistic approach that spans all network elements

The RAN consumes about 73% of an MNO's total energy use, primarily in the form of electricity, so improving its energy efficiency must be the main priority in sustainability strategies for telecoms operators. Although 5G radio standards support significantly better energy efficiency than previous technologies, these improvements are outweighed by other factors that increase power consumption, including a larger number of cell sites, base stations and frequency bands, all required to support rising traffic and quality demands.

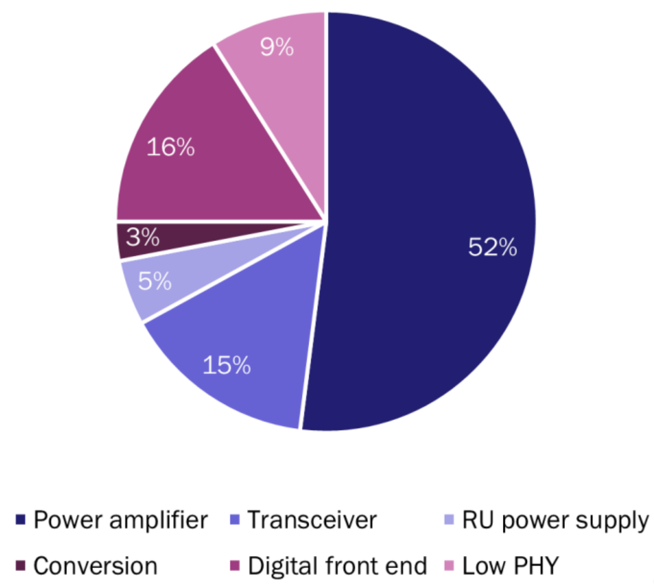
The telecoms industry has worked hard to reduce energy consumption using many tools, from AI-enhanced power management to liquid cooling on cell sites. However, one solution will not deliver the level of savings that operators require. A multi-faceted approach, that optimises energy usage across every component of the RAN, is the only way to maximise efficiencies, but different specific measures will be needed in each of the three main layers of the RAN, the passive infrastructure (sites), the digital baseband unit (BBU) and the radio unit (RU). Analysys Mason calculates that a strategy that spans all three layers can achieve up to 56% in energy and emissions reductions. The biggest savings can be made in the RU, and this article will focus specifically on that element.

Within the three layers, the RU typically accounts for 40% of total mobile network energy usage and 78% of base station consumption. The percentage of mobile network energy that is consumed by the RU is increasing as more sites and frequency bands are added to support 5G use cases, including high-frequency bands that require complex antenna technologies such as massive MIMO.

The PA consumes most energy within the radio network

Within the RU, the biggest consumer of energy is the PA, as Figure 1 illustrates. The PA is a key part of the digital front end (DIF), which is responsible for amplifying and converting incoming signals ready for transmission. The percentage of power consumed by the PA can rise significantly higher when a site is heavily loaded, even up to 90% in a fully loaded site with a typical 4T4R, dual-band 5G radio.

Figure 1: Typical breakdown of power consumption within an RU



Source: Analysys Mason

There have been efforts in recent years to reduce PA power consumption, through improvements in semiconductor design and in intelligent power techniques such as automatic wind-down or shutdown when radios are not in use. However, these incremental improvements will not keep pace with the rising demands on the RU – a completely new architecture is required, and operators are starting to invest in trials and deployments.

An example is Orange, which has introduced a brand new PA architecture to 400 sites since the end of 2023, as part of a network modernisation initiative, with the first sites being built in Cote d'Ivoire. This has resulted in RAN energy savings of 50% in the upgraded sites. The savings are derived from two main, interlinked changes – the replacement of five separate radios, one for each frequency band, with two multiband RUs; and the replacement of conventional PAs with those based on ZTE's Super-N architecture.

Emerging PA architectures seek to transform power efficiency by addressing several key challenges in radio frequency performance, notably:

- **Improving linearity.** Linearity occurs when the PA can amplify a signal without distorting its shape, which enables the output signal to be an accurate copy of the input signal, maximising quality of experience. Linearity becomes increasingly challenging where output power is high, for instance in typical mid-band frequencies where output power can be 300–400W. Digital pre-distortion (DPD) is the technique used by cellular PAs to enhance linearity, allowing the PAs to delivery higher quality and more effective power output.

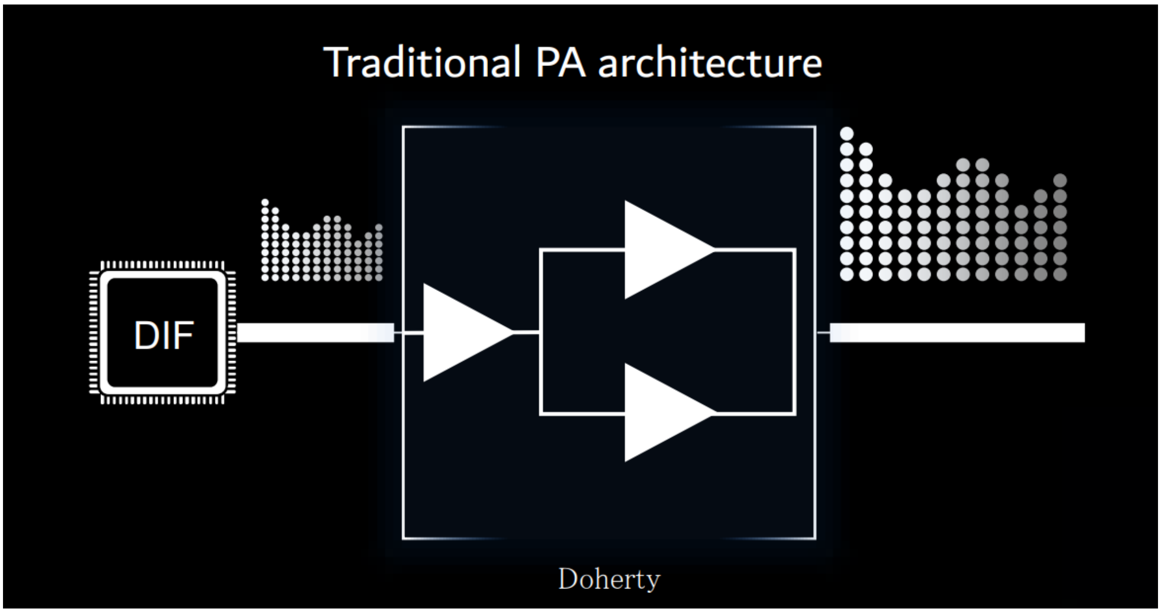
- **Boosting efficiency at low load.** Although fully loaded sites add to overall power consumption, power efficiency is greatly reduced when sites are operating with low loads, which is the case for most sites at most times of day. Improving efficiencies even with low loads is a significant challenge and has been the subject of many years of industry research.

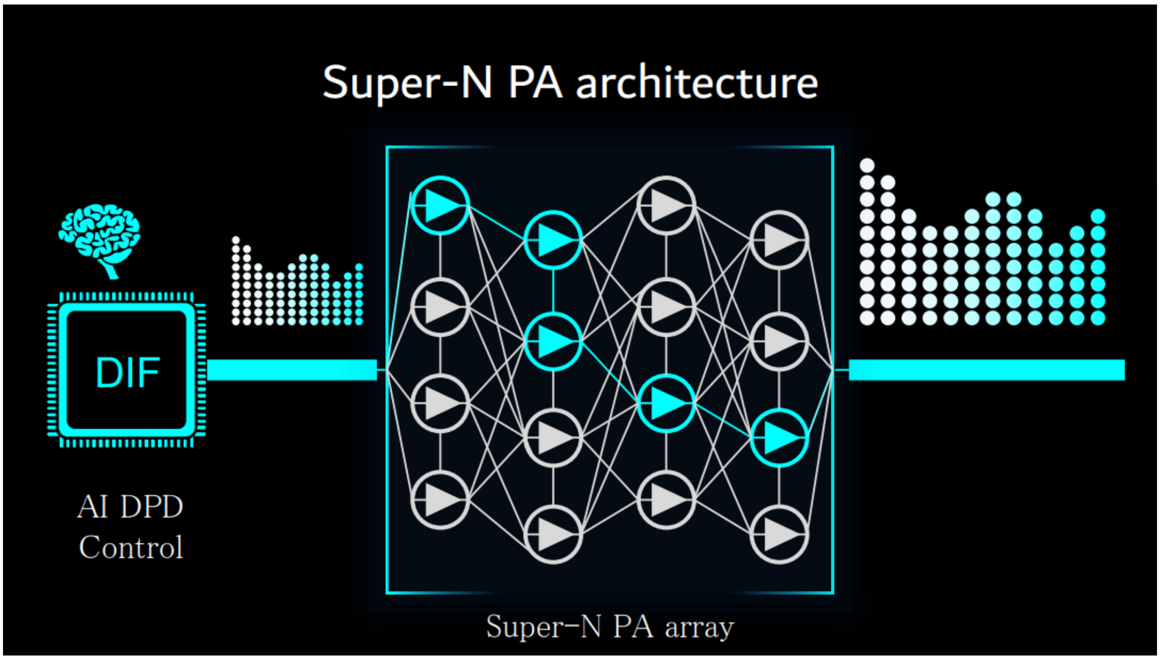
Conventional PA architectures have reached their efficiency limits, and a completely new design is essential for 5G

Super-N was developed to achieve near-constant power efficiency regardless of traffic load and at any level of output power. The new PA architecture relies on advances in transistor technology and array design. Traditional designs use a laterally diffused metal-oxide semiconductor (LDMOS) transistors and an architecture called 'Doherty', which consists of three transistors, two of which amplify the signal. This architecture is simple to implement but has reached its efficiency limits.

By contrast, Super-N uses gallium nitride, which supports high-power density and efficiency, and a new 'dense transistor array' PA architecture. This uses multiple small transistor dies so that amplification can be carried out in multiple stages and paths, which improves flexibility and linearity, and boosts overall PA efficiency by 8–10 percentage points, according to ZTE. An AI-enhanced DPD technology is used to detect the input signal and its characteristics and match these in real time to the required levels of PA activity, to ensure an optimum match with the output signal, at low power. This DPD enhancement enables on-demand adaptive activation for the elements within the dense PA array.

Figure 2: Comparison between traditional PA architecture and Super-N





Source: ZTE

Innovations such as Super-N will be essential for reducing total power consumption, and improving power efficiency, in the PA, which in turn will make a very significant contribution to MNOs' energy reduction goals and take them a step further towards the ambition of the net-zero RAN.