GaN for Power-Hungry 5G Base Stations

There is a significant change currently underway in the world of mobile telecommunications: the rollout of the fifth generation of cellular network technology, otherwise known as 5G. Consumers are only just beginning to experience the benefits of 5G technology, which will not only enable ultrafast download speeds to rival fixed-line broadband, but will in future also support a much higher density of mobile and connected IoT devices within cellular network areas. But that 5G will consume more power than 4G is an inescapable reality. GaN in SMD packages are a perfect match for the particular requirements of 5G network infrastructure. **Francesco Di Domenico, Principal Application Engineering, Infineon Technologies, Neubiberg, Germany**

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Exciting as this development may be for the consumer, behind the scenes the industry's move to 5G has been challenging, costly and controversial. Issues such as the allocation of radio frequency spectrum licenses [1], ill-informed myths stoking panic about the health risks of 5G for users [2], and the fallout from cybersecurity fears between international trade rivals[3] have dogged the migration process throughout.

Although 5G will no doubt be a profitable venture for cellular carriers and network operators, it will require an exponential upfront investment to upgrade, improve and replace the existing cellular network infrastructure. However, it is not just the upfront cost of the network overhaul that is likely keeping network operators awake at night, but the ongoing operational expenditure as well. The fact that 5G will consume more power than 4G is an inescapable reality; in fact, power consumption is predicted to rise by almost 70 percent as a consequence (Figure 1). For example, where a 4G base station might require around 7 kW of power, a 5G base station will need over 11 kW - and some stations carrying multiple channels could even consume up to 20 kW.

More of everything is needed

Even though the technology behind 5G networks are generally more efficient than 4G, the increased capacity of each cell will result in an overall increase in power consumption. The reason for this is the use of Massive MIMO (Multiple-Input, Multiple-Output) antennas over a single radio channel to improve signal quality. In comparison with 4G base stations, which typically use 4T4R (4 transmitters, 4 receivers), 5G base stations employ 64T64R.

It is thus no mystery to see why the demand for power is so much higher. Some 5G network providers struggling with the mechanics of delivering it are even debating the possibility of limiting the number of transceivers at base stations to 32T32R in order to save power, even though this would effectively throttle the capacity of the network.

To compound the issue of increased power demands at existing base stations, the other challenge is the need for more base stations than ever before. This is partly because the radio wavelengths particular to 5G technology have a more limited range, meaning that a greater concentration of base stations will be needed to provide given areas with effective coverage. The cost of building these new base stations and installing the power grid that will support them will be enormous.

Finally, there is the problem of power supplies; the industry standard of 3 kW 48 VDC will be woefully inadequate, even if the total amount of power required only doubles. Power density will therefore need to be increased significantly to deliver the same amount of power using a comparable amount of space.

Moving to the edge

5G networks will see the network map undergo significant change as increased processing power migrates closer to the edge where data collection actually takes place

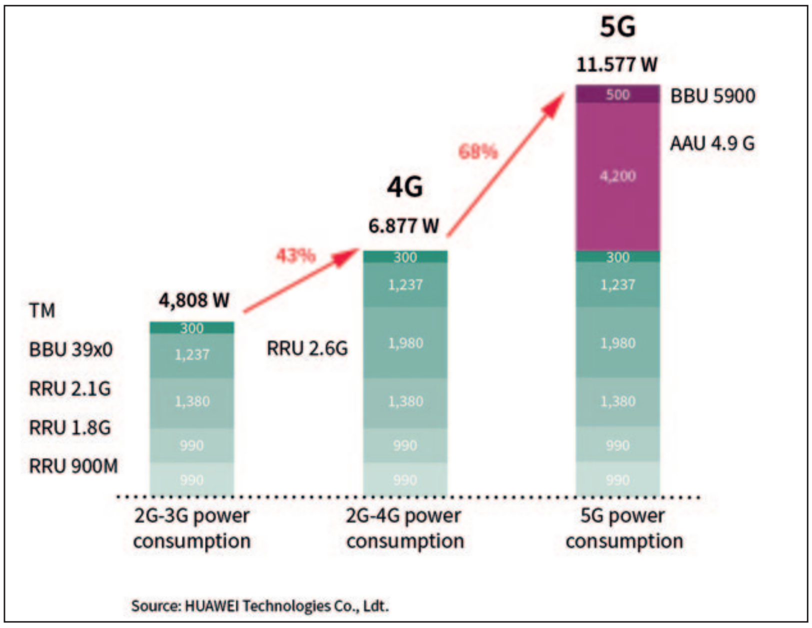

Figure 1: The power consumption of a typical 5G telecom site (Source: Huawei Technologies)

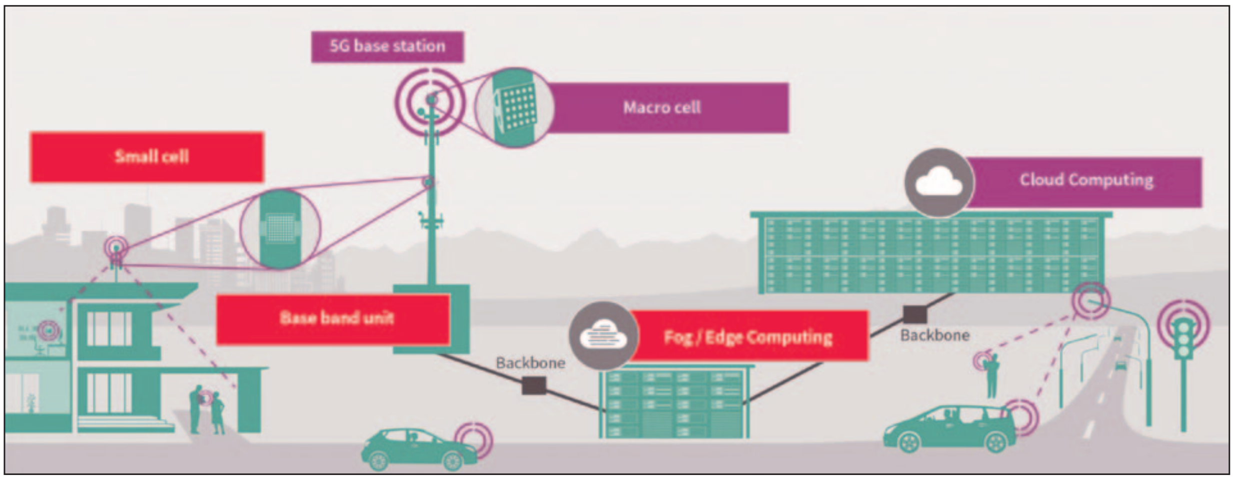

Figure 2: SMPS in the 5G ecosystem

(Figure 2). Not only will additional hardware be required to implement 5G, but the stations themselves will require more compute power to support the wider range of services that the new generation of mobile broadband will offer. As operators begin to deploy edge computing, the power architecture for each station will need careful consideration.

More power density, less heat?

It's clear from the points covered that some tough design challenges lie ahead. Support for the necessary power input can only be achieved by increasing the efficiency of the power conversion stage and will be instrumental to delivering more power in the same footprint. The key to this efficiency lies in a combination of gallium nitride (GaN) wide bandgap semiconductor technology and cutting-edge surface-mount design (SMD) packaging.

Unlike through-hole devices (THDs), SMDs are mounted directly on the surface of the PCB. The elimination of through-holes and leads as well as increased function density makes more space available on the board, thereby increasing power density capabilities.

However, increased power density can be a double-edged sword as it is usually delivered hand-in-hand with corresponding heat density. Packing more power into a given area can only be advantageous when heat density can be kept the same or, if possible, be decreased. SMD packaging offers a significant benefit in this regard as it allows for top-side cooling by putting the top of the package in direct contact with the enclosure, which is usually made of aluminum. This offers a much shorter thermal path for the heat to escape from the transistor junction to ambient air.

Using traditional Silicon semiconductors in SMDs will not be able to deliver lower heat density. Even though packaging technology continuously improves to offer better thermal conductivity, the device will still be limited by the operating temperature unless the semiconductor material inside switches more efficiently. Although Si MOSFETs have reached their upper limits of efficiency, new wide bandgap semiconductors such as silicon carbide (SiC) and GaN offer much higher efficiency.

In SMD packaging, GaN has certain physical properties that allow it to switch higher powers at higher frequencies than its Si counterparts, as well as offering a lower on-resistance ($R_{DS(on)}$) and significantly lower switching losses. Because the power converter can operate at higher frequencies, the power supply topology is simplified due to the lower number of magnetic discrete components required in the circuit, thereby allowing for greater power density. Moreover, GaN's inherent high efficiency means heat density can, in most cases, be reduced.

Figure 3 shows a Pareto analysis of all possible power density and efficiency combinations of a 3 kW 48 V PSU at 50 % load. It demonstrates that using Infineon's CoolGaN in power conversion solution could either result in higher efficiency, higher power density or a combination of both when compared to even the most state-of-the-art Si MOSFET solutions.

It is clear therefore to see that GaN in SMD packages are a perfect match for the particular requirements of 5G network infrastructure and enable network operators to deliver the power of 5G even in the most challenging places

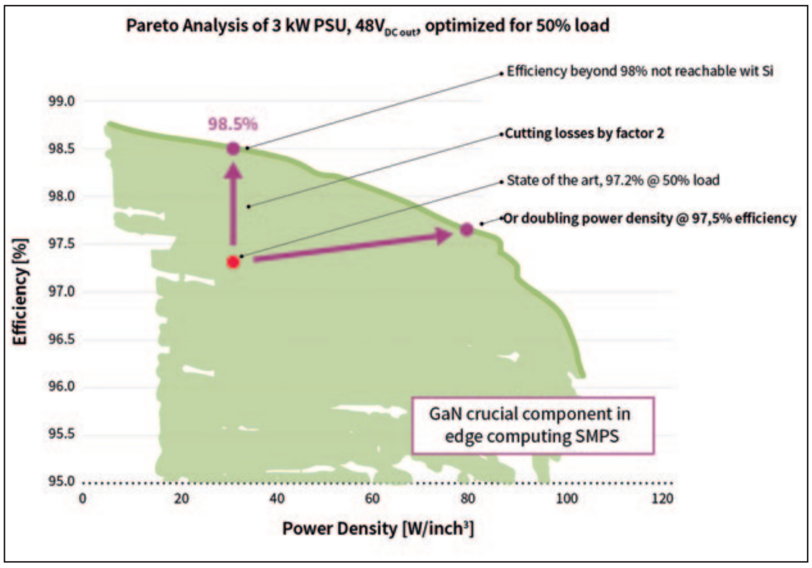

Figure 3: GaN can provide higher power density and greater conversion efficiency

References

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