

A technical look at 5G energy consumption and performance

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Emerging use cases and devices demand higher capacity from today's mobile networks, leading to increasingly dense network deployments. In this post, we explore the energy saving features of 5G New Radio and how this enables operators to build denser networks, meet performance demands and maintain low 5G energy consumption.

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Historically, densification of networks has implied higher energy expenditure which can add up to a significant part of operator expenses. This, in turn, can place restraints on the number of base stations in the networks.

5G New Radio (NR) is designed to enable denser network deployments and simultaneously deliver increased [energy efficiency](#), thus reducing both operational costs and environmental impacts. Before we explore the new technical features, let's look more closely at how the existing 4G LTE radio networks function.

The continued exponential growth in data traffic (Figure 1) has expanded mobile networks. This expansion has led to the energy consumption in radio networks becoming a significant contributor to the electricity usage and operational expenditures of operators. In recent years, we published a joint report together with network operator Telia which examined the [operational carbon emissions of ICT network operators](#). We found that, in 2015, ICT networks consumed 1.15% of the total electricity grid supply globally and contributed to 0.53% of the global carbon emissions related to energy. With new devices and use cases increasing the capacity of the networks, the demand to ensure low 5G energy consumption is critical to minimizing operator expenses and ensuring they can still meet energy reduction goals. How can NR bring an answer?

Global mobile data traffic (EB per month)

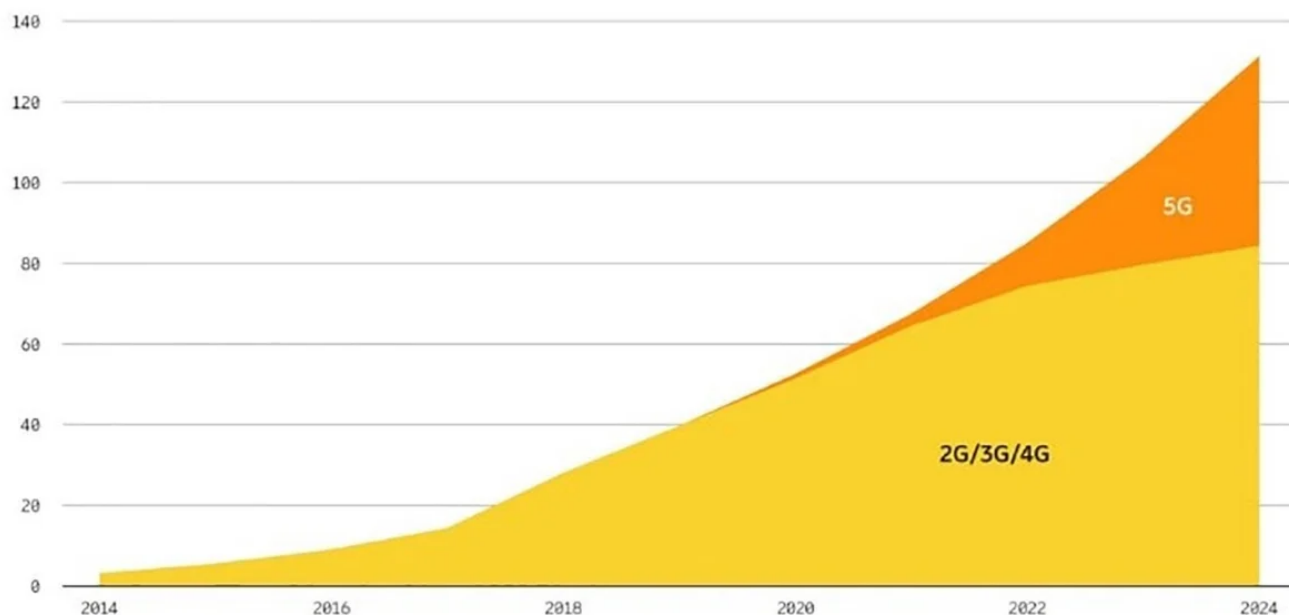


Figure 1: Global mobile data traffic outlook [Ericsson Mobility Report, June 2019].

Base station power consumption

Today we see that a major part of energy consumption in mobile networks comes from the radio base station sites and that the consumption is stable. We can also see that even in densely deployed networks, as in city centers, the network traffic load can fluctuate very much during the day, with significant periods of almost no traffic in the base stations (read more in this [ITU-R report](#)). When further examining the traffic patterns, we see that there are many short gaps in the data transmissions even during highly loaded times (Figure 2). This raises an obvious question: if the base stations are spending so much of their time not transmitting

user data, why are they still consuming energy all the time?

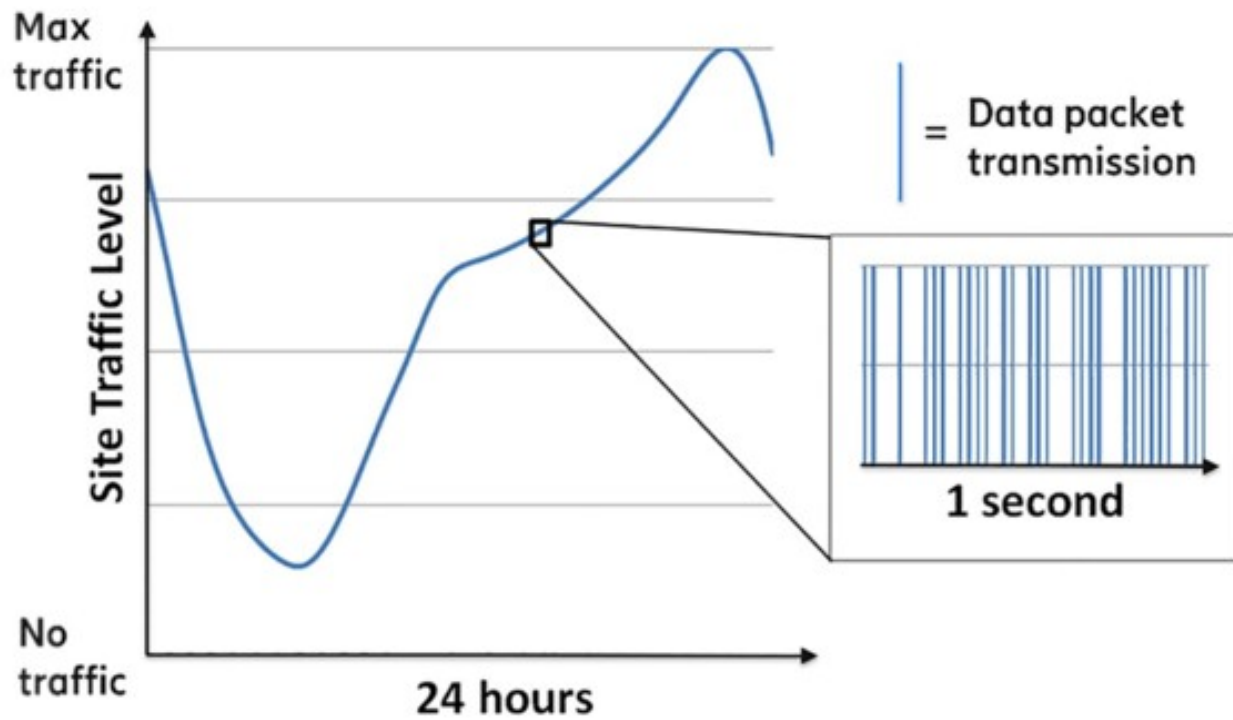


Figure 2: Varying network traffic load during the day. The highlighted part shows the gaps in data packet transmissions during a high-traffic situation.

To understand this, we need to look closer at the base station power consumption characteristics (Figure 3). The model shows that there is significant energy consumption in the base station even at the times when there is no output power i.e. when the base station is in an idle state. The reason for this is that most of the hardware components still remain active so that they are able to transmit mandatory idle mode signals that are defined in the 4G standard such as

synchronization signals, reference signals, and system information. So, how can we use this knowledge to create features for energy saving in 5G NR?

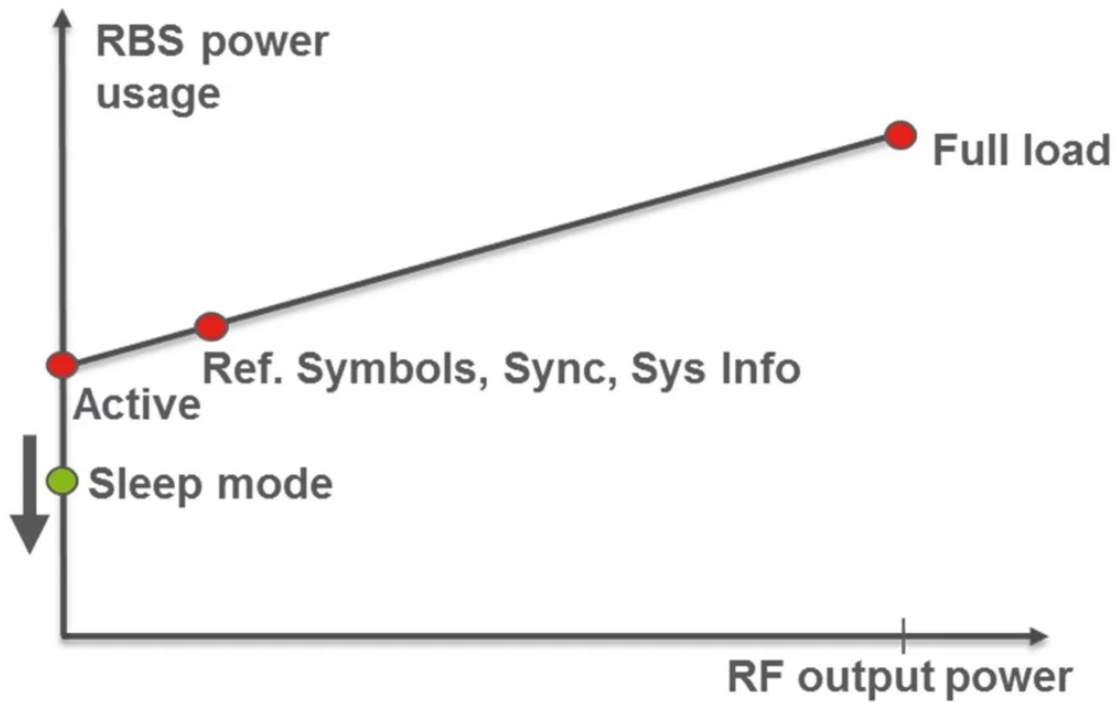


Figure 3: Base station power model. Parameters used for the evaluations with this cellular base station power model.

Energy saving features of 5G New Radio

The 5G NR standard has been designed based on the knowledge of the typical traffic activity in radio networks as well as the need to support sleep states in radio network equipment. By putting the base station into a sleep state when there is no traffic to serve i.e. switching off hardware components, it will consume less energy. The more components that are switched off, the more energy we will save (shown on the y-axis in Figure 3).

In previous network technologies, such as LTE, there are frequent transmissions of always-on signals, like for instance cell specific reference signals (CRSs). These are needed to secure cell coverage and good connection with users. As a result, there are only very short durations (less than 1 ms) for the base station to sleep

until the next required signal transmission occurs and only a small number of components with very fast reactivation times can thus be switched off when the base station is in idle mode, and this limits the possible energy savings of LTE.

NR, on the other hand, requires far less transmissions of always-on signaling transmissions. This, in turn, allows for both deeper and longer periods of sleep when there are little or no ongoing data transmissions, which has a significant impact on the overall network energy consumption (Figure 4).

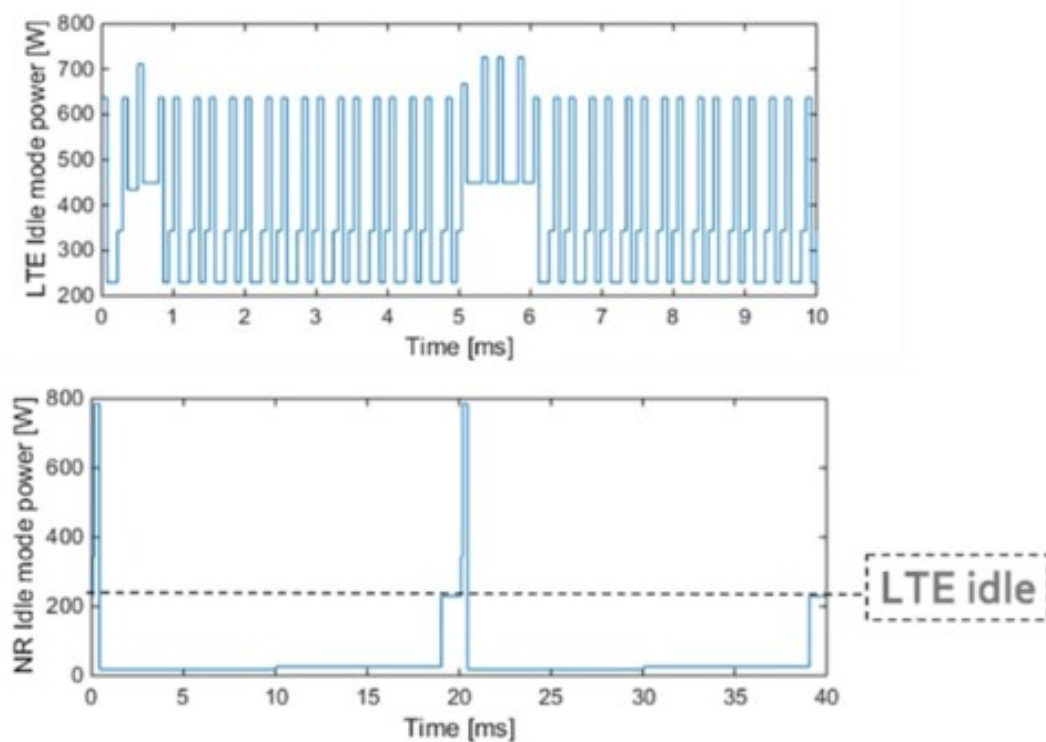


Figure 4: Example of base station energy consumption during idle mode signaling in LTE (top) and NR (bottom). NR is configured to send signal blocks (SSB) every 20 ms.

How much energy can we save with NR sleep modes?

The first deployments of NR are mainly [non-standalone](#) (NSA) deployments. This means that existing LTE base stations will still be used, and NR will be added for more capacity to meet the increased demand in data traffic. In many cases, this additional NR layer will be part of a heterogeneous network (hetnet) type of deployment, using smaller micro cells deployed inside the existing macro cell.

We have evaluated the impact of NR on network energy expenditure and user performance, by performing simulations of a radio network using the existing LTE infrastructure and then adding NR or LTE layers on top as micro nodes (Figure 5).

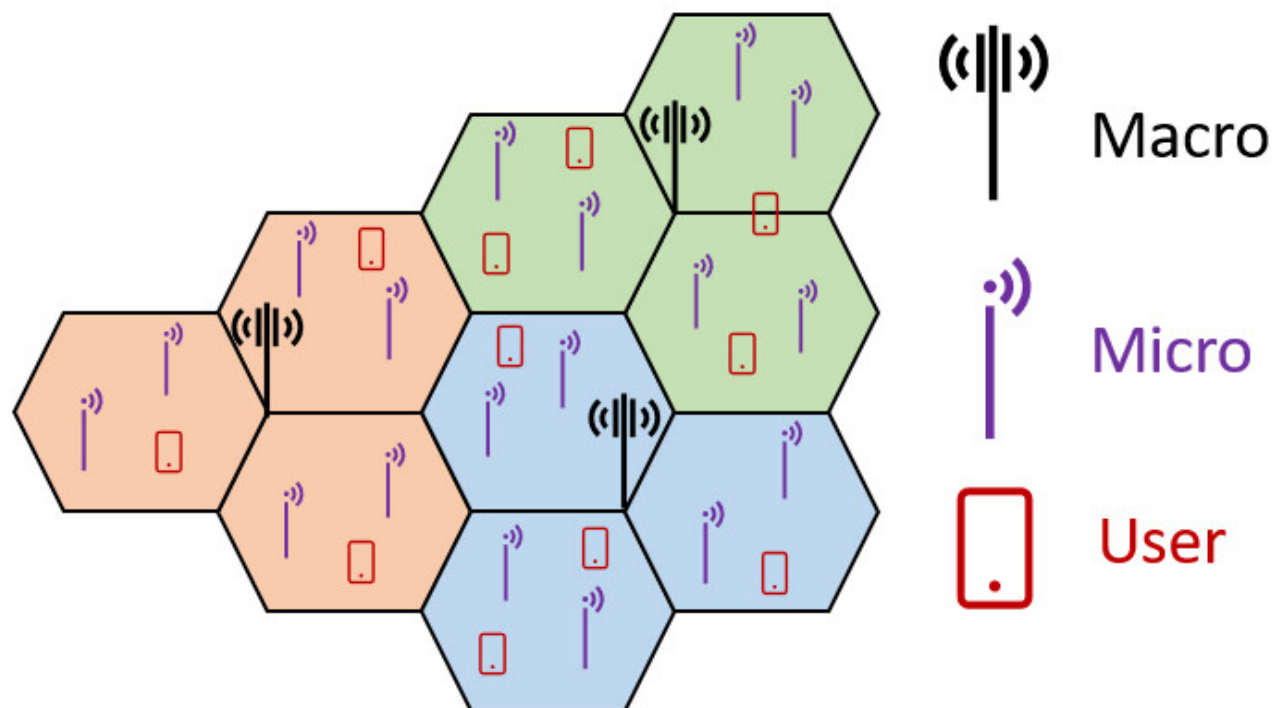


Figure 5: Example of a multi-cell and multi-user simulation scenario.

Simulations have been performed with hexagonal cells in a Super Dense Urban scenario (city centers) with an inter site distance of 380 m (distance between macro base stations). The NR (or extra LTE) layer consists of additional 1-4 micro cells per macro cell. The frequency bands used are 0.9 GHz for the macro layer

and 3.5 GHz for the micro layer (see Table 1 below).

| Simulation parameters | Macro | Micro |
|---|----------------------------------|---------------|
| Site type | Hexagonal 3 sector | Single sector |
| Radio Access Network | LTE | NR/LTE |
| Number of Antenna Elements | 2 | 64 |
| Frequency [GHz] | 0.9 | 3.5 |
| Bandwidth [MHz] | 10 | 40 |
| BS Transmit Power [W] | 40 | 20 |
| BS antenna height [m] | 25 | 10 |
| Scenarios | Super Dense Urban (SU) | |
| Propagation | 3GPP spatial channel propagation | |
| ISD [m] | 380 | |
| DL FTP traffic [MB] | 2 | |
| Indoor ratio [%] | 80 | |
| UE antenna height [m] | 10 | |
| Traffic load target [Mb/s/km ²] | 750 | |

Table 1: Simulation parameter settings.

Impact on energy efficiency and performance in a Super Dense Urban scenario

We start by looking at the impact on user performance when introducing NR (Figure 6). We can notice that the LTE-only network is not sufficient to serve the expected 2020 peak hour traffic of 750 Mbps/km² predicted in Ericsson's Mobility Report back in 2015. When we add NR micro cells, both capacity and user

performance increase significantly.

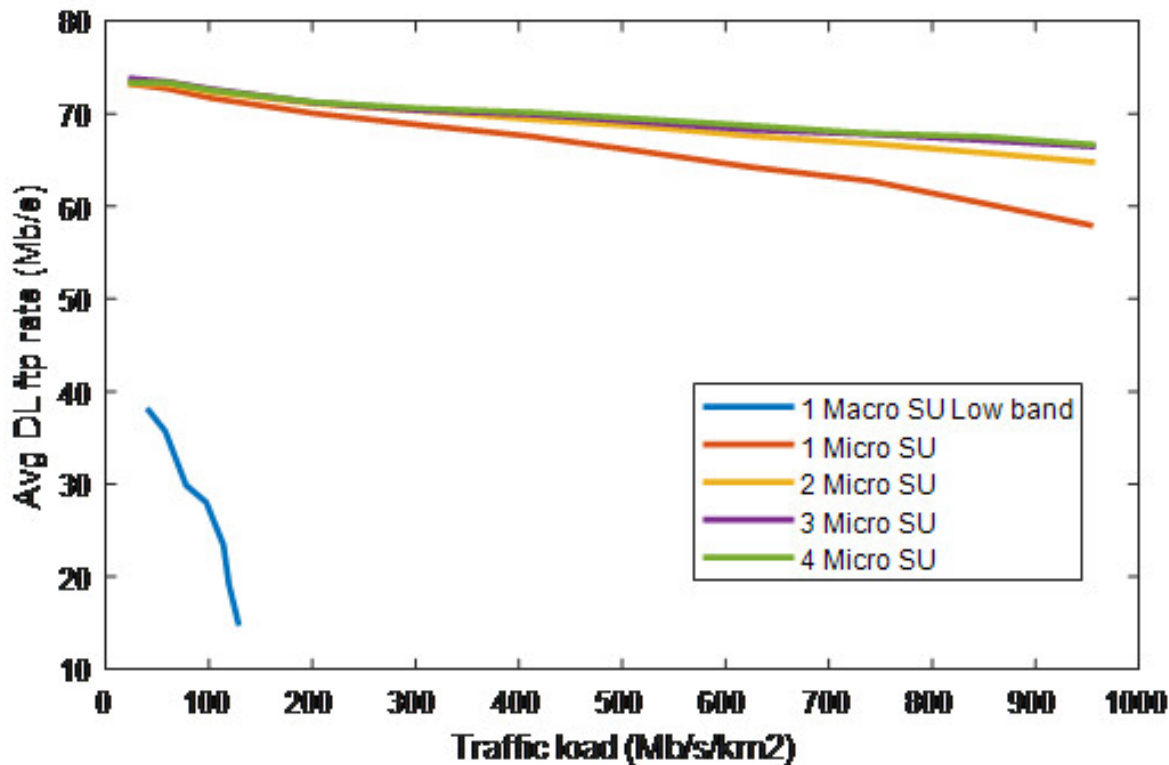


Figure 6: Super Dense Urban (SU) hetnet, traffic load curves.

We now turn to look at the energy consumption of various networks deployments over the course of a day. Figure 7, below, shows the daily power curves for a hetnet deployment of LTE macros and NR micros.

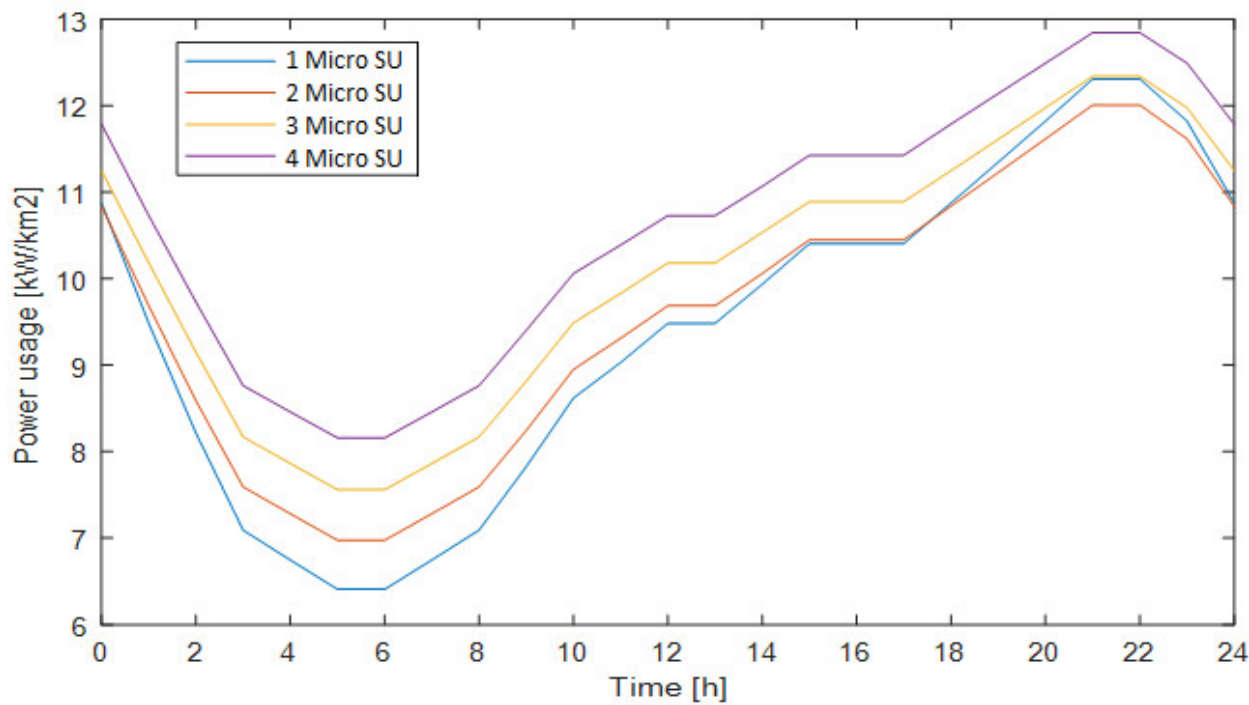


Figure 7: Super Dense Urban (SU) hetnet daily power usage curves, with the peak hour traffic of 750Mbps/km² reached at 21h.

We can see that the energy consumption varies during the day because of the varying traffic loads. At the low traffic point (around the 06:00 mark) the 1 NR micro deployment consumes the least energy, but at the high-traffic point (around the 21:00 mark) the 2 NR micro deployment consumes less. In this highly loaded case,

the added capacity results in quicker transmissions, thus more time to sleep and reduced power consumption. This shows that an optimal deployment from an energy efficiency perspective varies with the traffic scenario.

Figure 8 depicts the total 5G energy consumption in the same test area during the day. Here, we compare the LTE-only deployment in the left bars, with the LTE and NR deployment in the middle bars and the NR-only deployment in the right bars. A clear trend we notice is that by using NR deployments, we decrease the energy consumption significantly. What we also can see is that every addition of an LTE micro node makes for a considerable increase in the power consumption. When using NR this is not the case anymore, as each addition of a NR micro node only results in a very small increase in the energy consumption. The reason for this is that the added capacity with more micros open for the possibility of offloading traffic between the nodes, and each single node can stay idle for long periods. As described before, the NR technology can take advantage of this idle time and use it for deep sleep and low energy consumption.

Lastly, in the right-most set of bars, one can notice that there is also a small decrease in the macro layer power consumption when adding extra micros. This is because of the extra offloading of the macro layer when adding more micros and thus when switching the macros to NR they have the same advantage of utilizing the deep sleep.

From this we can conclude that deploying a dense network using NR can offer both high performance and capacity (Figure 6) while ensuring low energy consumption (Figure 8).

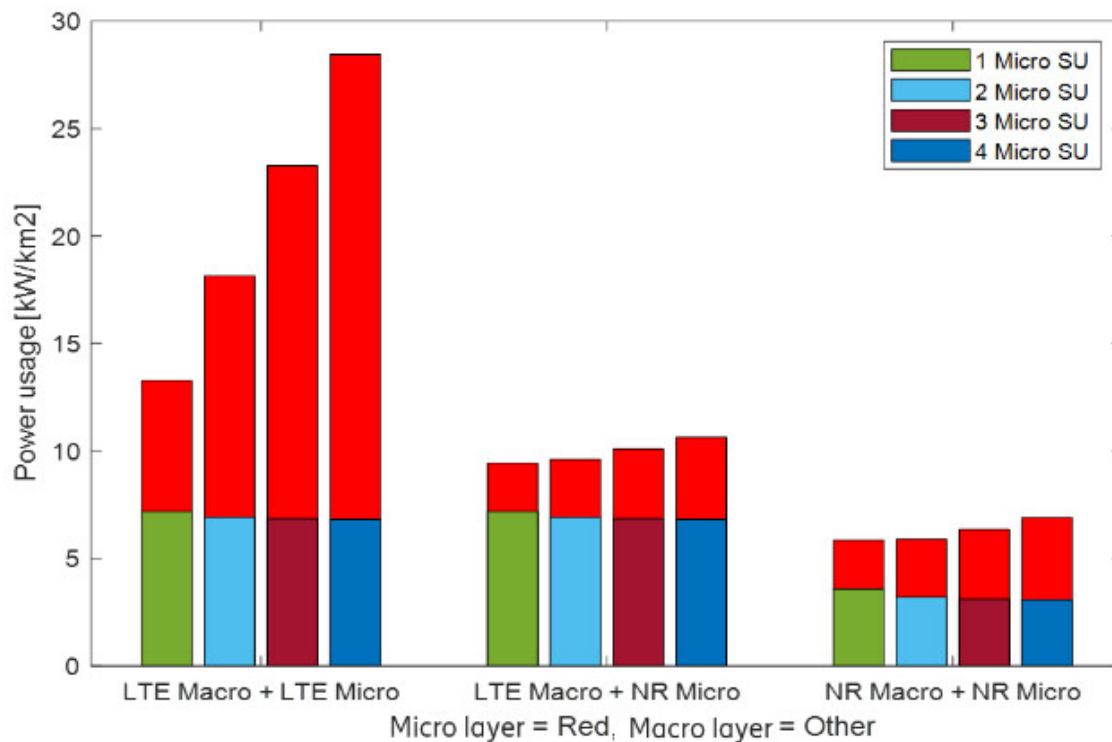


Figure 8: Super Dense Urban (SU) hetnet, total daily power consumption.

Further reading

Ericsson has made a significant contribution to the standardization of the New Radio's energy saving features. Parts of this process were documented in our earlier articles about [radio network energy performance](#) and [energy performance of 5G NX](#).

Visit our earlier [5G energy efficiency](#) blog post to find out how the development of new radio is enabling us to meet our own product energy performance targets at Ericsson.

Find out more about [Ericsson and sustainability](#).

This blog post is based on a conference paper by the same authors, published in summer 2019. Read the paper in full here: "[More Capacity and Less Power: How 5G NR Can Reduce Network Energy Consumption](#)".



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