GREENWAVE
WIRELESS RESEARCH

Enabling a Sustained RAN for a Greener Bottom Line

White Paper - August 2020

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OUR VISION

We believe wireless and ICT industries should lead a sustainable world.

OUR MISSION

Our mission is to inform, support, and promote the use of green wireless and ICTs to support lower carbon emissions and sustainability.

We work with innovators, entrepreneurs, service providers, tech vendors, associations, and NGOs to provide in-depth research, analysis, and news of eco-friendly technologies and use cases.

A GREENWAVE MANIFESTO

" WE NEED GREEN WIRELESS NOW "

1 **THE WIRELESS INDUSTRY MUST BECOME CARBON NEGATIVE**
The wireless industry has the potential to enable emissions reductions much greater than its own emissions.

2 **REDUCE WASTE FROM MOBILE DEVICES**
Safely reuse, recycle, or dispose of products or components; maximize the use of existing products and systems

3 **REDUCE THE IMPACT OF MOBILE DEVICES**
Assess and reduce the impact of using rare minerals—such as tungsten, tin, and neodymium—extracted from conflict-torn areas

4 **ENABLE LOWER ENERGY CONSUMPTION**
Use energy-efficient solutions in base stations and data centers; encourage RAN sharing and single RAN kits

5 **ASSESS THE IMPACT OF 5G ON THE ENVIRONMENT**
Are millimeter waves safe for humans? Wildlife? How can we reduce the impact of small cells on the environment?

6 **SUPPORT GREEN AGRICULTURE**
Leverage wireless technologies—such as cellular and LPWAN—to support smart and less-invasive agriculture

7 **LOWER GREEN HOUSE GAZ EMISSIONS**
Use wireless technologies in smart meters, smart grids, and smart buildings to lower GHGs

8 **IMPROVE QUALITY OF LIFE FOR CITIZENS**
Measure air and water quality, as well as any sort of pollution

9 **PROTECT NATURAL HABITATS**
Track and protect endangered species; use satellite, IoT, drones to measure reforestation initiatives and detect forest destruction

10 **SUPPORT CARBON OFFSETTING**
Measure and support carbon offsetting initiatives across all industries

Enabling a Sustained RAN for a Greener Bottom Line

The telecom industry consumes between 2-3% of the world's energy according to the GSMA, and energy consumption for mobile network operators accounts for 20-40% of network opex[1].

This bill is set to increase as operators roll out 5G technology. The promise of gigabit speeds has a price: cell sites need more power to run 5G services. The amount of power 5G requires is significant and has many operators thinking carefully about related trade-offs. For their part, vendors are rapidly evolving their 5G gear to incorporate the latest technologies and introduce new techniques to improve the efficiency of wireless infrastructure.

In this paper, we provide an overview of power consumption in mobile networks. Our objective is to bring awareness to this important subject. We also address some of the key elements that operators and vendors are taking to manage energy consumption in mobile networks.

[1] Energy Efficiency: An Overview, GSMA, May 8, 2019. https://www.gsma.com/futurenetworks/wiki/energy-efficiency-2/

Power Consumption in Perspective

Three key elements account for the power requirements of mobile base stations: the number of frequency carriers, the bandwidth of the carrier, and the number of antennas at the cell site. To achieve gigabit per second speed, operators deploy more spectrum, wider channel bandwidth, and a higher number of antennas. In fact, successive technologies are designed to support more frequency carriers that have wider bandwidth in addition to more antennas. For example, an LTE frequency carrier is 20 MHz versus 100 MHz for a 5GNR carrier. Moreover, it is not uncommon for a single operator today to hold 200-300 MHz of spectrum. Recent 5G spectrum auctions in the 3.5 GHz band, for example, are often based on 80-120 MHz carrier allocations.

As a case study of power consumption in communication networks, Vodafone Group reports in their 2019 sustainability report that wireless base stations used 3,684 GWh, or 66%, of total energy consumption. In comparison, the rest of their network used less than half of that amount, including switching and data centers: 1,571 GWh. With 164,000 base stations, this averages to 2,564 W per base station that includes a mix of 2G, 3G, and 4G technologies. If the cost of electricity is $0.1 / kWh[2], this amounts to $368 million per year to power the radio access network alone.

The addition of 5G may well double the power consumption. For instance, a single 64-branch massive MIMO radio over 100 MHz carrier consumes about 500 W, or more, depending on vendor. A 3-sector 5GNR site and the corresponding baseband could add in excess of 2,000 W. Vendors compete on power consumption requirements and invest heavily to improve the power efficiency performance.

5G power requirements translate into additional expenditures for the service provider beyond the recurring cost of power. This includes the cost of upgrading the cell site power supply unit and battery backup, and perhaps the HVAC unit. Sites in urban areas are often cramped with little free space, making the addition of batteries or a bigger HVAC unit impossible. These are some practical considerations with which operators must contend. In fact, South Korean operators initially deployed 32-branch massive MIMO 5GNR systems instead of 64-branch systems because of power requirements, even though the 32-branch systems obviously provide half the capacity.

[2] Cost of energy varies widely by market and geography and can easily range between $0.02 – $0.25 / kWh.

Cell Site Power Optimization

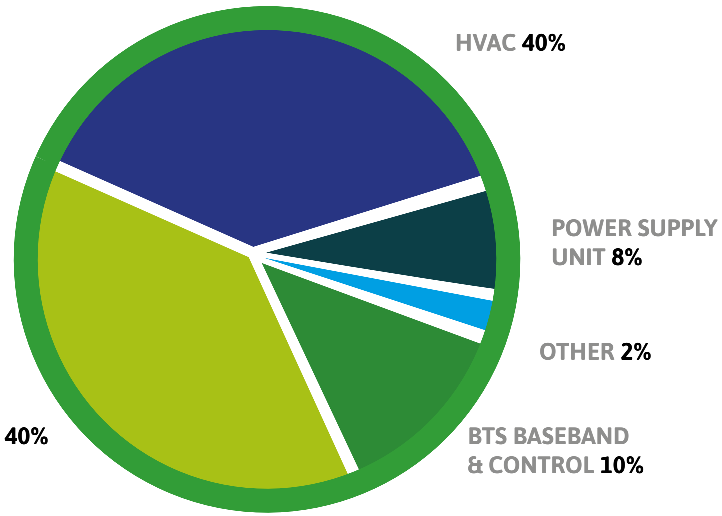
The radio unit and HVAC systems account for up to 80% of power consumption in a wireless base station. For this reason, vendors and operators quickly realized that adopting a distributed base station architecture where the radio unit is remotely placed close to the antenna has good economics. Moving radios out of the equipment room and placing them close to the antenna reduces HVAC requirements. Moreover, it eliminates as much as 50% of the attenuation losses incurred in long feeder cables connecting the radio to the antenna. This allows operators to reduce the RF output power setting which saves more energy. 5GNR goes a step further by integrating the power amplifiers with the antenna to maximize power efficiency and enable massive MIMO and beamforming.

Cell Site Power Consumption Breakdown

The design of the radio module is a matter of pride for vendors who strive to maximize its efficiency. There are different techniques to achieve this, including the architecture of the RF and power amplifier circuitry, algorithms such as digital-pre-distortion and crest factor reduction techniques, and the silicon which runs these algorithms and other digital functions in the radio unit. For instance, leading vendors use state-of-the-art 7 nm lithography process and aim to migrate to 5 nm process post 2021.

Vendors invest millions of dollars in ASICs and SoCs to make radios and baseband run efficiently while minimizing power consumption. Power efficiency translates into smaller form factor and lighter equipment weight which is very important for practical reasons and has direct impact on network deployment costs. For instance, vendors aim to develop tower-top radios that weigh less than 20 kg to allow a single-person install possible. Regulations for deploying equipment on the tower-top would otherwise require multiple persons and cranes. Also, efficient baseband modules would reduce the capacity requirements of the HVAC unit and reduces capital and operational site costs.

Cell Site Power Consumption Breakdown [3]



[3] Source: Huawei, Enable Autonomous Driving Network, Huawei Network AI Engine (NAIE) Whitepaper, 2019

Power Optimization in 5G

Mobile traffic drives activity on wireless base stations and consequently power consumption. 5G incorporates sleep modes where the base station can power down its RF transmitters during traffic gaps even when they are very short. This feature was missing from prior technologies and would result in large savings because base stations are active for about 20% of the time.

There are additional features that 5G leverages to improve power efficiency, although their impact is smaller than the sleep mode. These features center on maximizing the efficiency of communication in order to allow more sleep time. This includes separate control and data planes which provide more bandwidth for user traffic, high data transmission rate, data compression to reduce traffic volume, and reduction in retransmitted packets with the Multipath Transmission Control Protocol. Another aspect of power optimization is using network function virtualization techniques to run applications on demand. This allows sharing of the computing infrastructure and helps to reduce energy consumption. Implementation of cloud-native core network is currently underway in the market. Virtualization of the radio access network is more complex than that of the core and more analysis would be needed to fully assess its benefits from a power consumption perspective.

Network Level Optimization

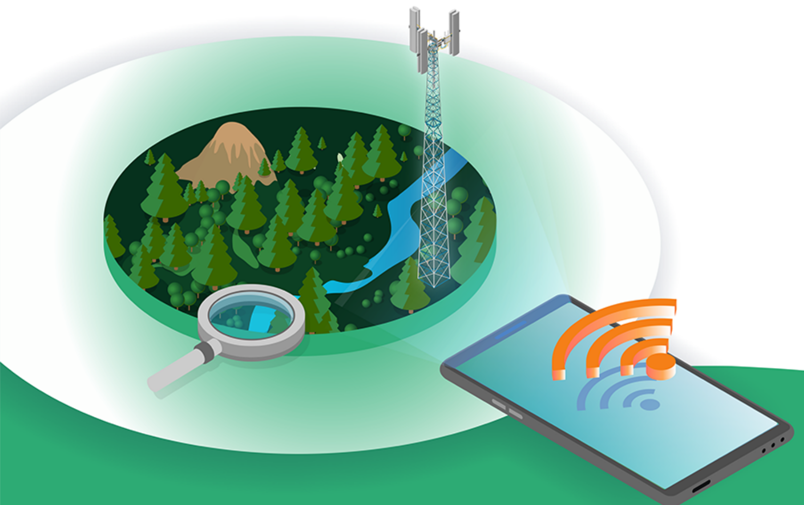
Power management was part of the Self-Organizing Network (SON) concepts which date back more than ten years. At that time, networks were relatively simple; for example, initial LTE networks were for a single frequency carrier. Power management through SON was not a priority for service providers who could improve efficiency implementing site-level optimization (including adopting remote radios and baseband modules that run different combinations of access technologies, e.g. single RAN solutions first commercialized by Huawei).

Gradually, as more frequency carriers were deployed to scale network capacity, networks became more complex. For example, today NTT Docomo in Japan runs 4-carrier aggregation, which includes FDD and TDD modes spanning 800 MHz, 1700 MHz, 2100 MHz, and 3400 MHz bands. 5G introduces yet another layer of spectrum, including millimeter waves which operate over 800 MHz channel bandwidth that dwarfs any single-operator holds in the sub-6 GHz bands.

As network complexity increases, it becomes more important than ever to take a holistic approach to power optimization. Service providers initially resisted this type of power optimization because it involved selectively turning off a frequency carrier which would lead to a coverage and/or capacity hit.

This could have been the case when a single LTE carrier was active along with 2G and/or 3G technology. However, the situation is different today with multiple operating frequency carriers. Moreover, artificial intelligence technologies are more readily available to leverage in this optimization process than in the past.

Network-level optimization could be implemented in different ways. One possibility is to use AI to predict traffic distribution in a network which is possible since traffic patterns are generally predictable over time and across the coverage area. This information is consequently used to work out the best plan to begin powering down certain elements of the network, while at the same time ensuring no degradation in service quality. For example, it would be possible to power down a frequency carrier, a power amplifier, a time slot, or a symbol. An example of this solution is Huawei's PowerStar which enacts power savings at three levels: network, site, and equipment. The system shows between 10-15% reduction in power consumption with possibility for greater savings in future 5G networks.



Savings from Deploying Power Consumption Automation Techniques [4]

SERVICE PROVIDER	POWER SAVINGS	KWH/DAY SAVED
China Mobile	12%	1.89
MTN	12%	6
Inwi	17.9	8.5
Axiata	11%	7

A 10% reduction in power consumption equals about $220/year per base station in power operating costs for the service provider [5]. With about 6-7 million macro cells deployed around the world, the total savings amounts to hundreds of millions of dollars. As 5G rolls out, even more savings could be realized.

[4] Source: Huawei
[5] Based on 2,500 W base station power and $0.1 / kWh price of electricity.

Power Consumption in Virtual RAN Networks

Virtual RAN refers to an implementation of the base station on general purpose processors. This is not to be confused with open RAN which refers to open interfaces between the base station subsystems (such as radio and baseband). Open RAN may be based on virtual RAN among other implementations.

Virtual RAN involves making trade-offs between software flexibility and hardware efficiency. Depending on how virtual RAN is implemented, it could lead to higher or lower power consumption. In either case, the impact of virtual RAN is associated with the baseband units, accounting for about 10% of the total site power consumption. For the time being, we are at the early stages of virtual RAN evolution; hence, it is something to monitor over time.

Digital Transformation and Sustainability

Vendors are paying increasingly more attention to network automation and network-level power consumption. In part, it is a way to differentiate a solution offering and compete against other vendors in providing state of the art tools to reduce service providers' operational costs. However, it is ultimately the responsibility of the service providers to adopt such tools and develop processes around them.

The service providers have to weigh the costs and benefits of the tools the vendors provide. SON is an example of an idea that failed to gain wide market traction for different reasons. While some aspects of SON were deployed by service providers, many aspects were not implemented, i.e., those related to power consumption. One would expect this to change with 5G because of its high demand for power and the complex nature of modern networks that makes automation tools necessary. Therefore, network automation is an integral aspect of the service provider digital transformation process for improving operational efficiency.

Another aspect is to consider the source of energy used to run telecom networks. Many service providers report on their energy source. Their annual sustainability reports show an increase in using renewable energies. There is one particular aspect where power efficiency plays a critical role: deployments where the power grid has low availability necessitating secondary sources of energy. Renewable energy such as solar panels become more practical than diesel generators where the base station power consumption is low.

Measuring Power Efficiency

Service providers annually report their energy utilization. Some even break it down into different components attributed to different parts of their operation. To track progress, they typically use Wh/B. For example, in 2019, Telefonica reported 115.2 MWh/PB based on 6,958,516 MWh for 60,406 PB of transmitted data. Moreover, some service providers account for the source of their energy including the renewable energy portion.

While reporting power consumption as a function of carried traffic is important, we need to be careful in interpreting such metrics. Wireless protocols are designed to pack more bits for over-the-air transmission which continues to increase with every successive generation. We have also seen the measures that vendors and service providers take in order to keep power consumption in check. A metric such as Wh/B, or Joule/bit, is bound to decrease, but the overall demand for power is not decreasing.

To illustrate, a 100 MHz 5G carrier will require around 2,000 W of power. This is in addition the power already used at the cell site by LTE and older technologies. The demand for power is not getting smaller, as power will be needed to run more of the equipment. However, the spectral efficiency is improving; the spectral efficiency for 5G could reach 10 b/s/Hz versus 2 b/s/Hz for LTE.

Finally, as networks become more sophisticated, the industry needs to develop metrics that account for operational efficiency. The reason for this is to provide a way to track the progress of implementing network automation for power consumption as part of the digital transformation process. Such a metric would provide a focus for the industry to proceed with automation techniques that characterize the “smart network.”

Concluding Remarks

Reducing carbon footprint starts with implementing a comprehensive energy efficiency strategy for the wireless networks. Long-term sustainability is the result of multiple factors that address energy consumption at every level of the network, starting from the component level through subsystems and culminating in a network level approach that leverages automation. In executing on such a strategy, it will be necessary to have a realistic view of the strain on capex and ensure it is not a barrier to energy savings that are characteristically operational and realized over time.

About the Author

Frank Rayal is a Partner at Xona Partners and a contributor at Greenwave Research. His focus is on enabling companies generate revenues through technology innovation and market insight. For over two decades, Frank worked to bridge the divide between technologies and markets by leading new product introductions through the entire lifecycle from concept to roll-out. Frank co-founded wireless pioneer BLiNQ Networks. He held senior product management, marketing, and business development positions at Ericsson, Redline, and Metawave. He holds a BS in electrical engineering from Case Western Reserve University, Cleveland, Ohio, and a MASc in electrical engineering and an MBA from the University of Toronto, Canada. He is a senior member of IEEE and a member of Professional Engineers Ontario.

GREENWAVE WIRELESS RESEARCH

About Greenwave Wireless Research

Greenwave is a boutique analyst firm. Its mission is to inform, support, and promote the use of green wireless and ICTs to support lower carbon emissions and sustainability. We work with innovators, entrepreneurs, service providers, tech vendors, associations, and NGOs to provide in-depth research, analysis, and news of eco-friendly technologies and use cases. GreenWave is led by veteran wireless analyst and influencer Adlane Fellah over 23 years' experience in the telecom sector.

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ANNEXES

GREENWAVE
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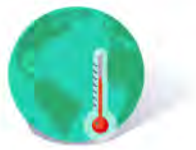
Why Care about Sustainability?



Demonstrate Leadership

The right thing to do given climate change externalities.

Reduce Costs

By using greener energy sources and more efficient processes.

Good Marketing

Show your customers you are a purpose-driven and value-oriented company.

Engage Stakeholders

By motivating and retaining staff and by demonstrating to investors that you are measuring, disclosing and managing climate risks.

Mitigate risks

Being proactive reduces the risk of being left behind when regulation is imposed.

Main Areas of Coverage

VERTICALS

- Smart Environment
- Smart Agriculture
- Smart Cities
- Smart Buildings
- Smart Energy & Water

WIRELESS & ICT

- Energy Impact of RAN and Data centers
- Impact of 5G on the environment
- Smartphone recycling and re-use

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Our Services

Lead Generation Webinars

We generate high-quality leads by organizing flawless webinars. We take care of all logistics, promotion, and coordinate content preparation.

White Papers

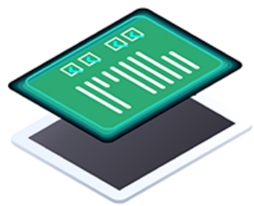
Demonstrate thought leadership and expertise by producing in-depth white papers on a particular topic of relevance to your audience.

Curated Blogs

We produce relevant, strategic, and trusted blogs to support your content marketing strategy.

Market Studies

We have more than 20 years of experience producing in-depth market reports, case studies, and research briefs for the wireless industry.



Online Surveys

We conduct telephone interviews and online surveys to extract market trends and generate primary research findings.

Green Talks

We conduct regular video interviews with the leaders of the industry and highlight their achievements.

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Mr. Fellah is a veteran industry analyst and influencer with 20 years experience in the telecom sector. He authored various landmark reports on Wi-Fi, LTE, 4G and technology trends in various industries including retail, restaurant and hospitality. He is regularly asked to speak at leading wireless and marketing events and to contribute to various influential portals and magazines such as *RCR Wireless, 4G 360, Rethink Wireless, The Mobile Network, Telecom Reseller* to name a few. He is a Certified Wireless Network Administrator (CWNA) and Certified Wireless Technology Specialist (CWTS). He also regularly serves as Glomo Awards (GSMA) and WBA Awards judge.

CAROLINE GABRIEL

ADVISOR, RETHINK RESEARCH

Caroline operates as the company's advisor. She is expert in all forms of Wireless communication and has edited the research service *Wireless Watch* since its inception in 2002.

