Expert View

by Brian Zahnstecher

The 5G Energy Gap

There is no shortage of hype and excitement when it comes to discussions about the next-generation cellular network, now in the process of production deployment worldwide, known as *5G* (or *5G New Radio* or the *Third Generation Partnership Project Release 15 standard* [1], to be more accurate). Combine this with all of the marketing projections for the many billions of (or even trillions, depending on your definition) smart devices, wearables, trackers, Internet of Things (IoT) and Industrial IoT applications, autonomous vehicles, virtual/augmented reality (VR/AR) equipment, and so on, and it seems like there is a pretty exciting marriage of a massive network with an explosion of devices to reshape our daily lives. But hold on a second: Almost every marketing projection and "killer app" (apologies for this overused buzzword) starts with an assumption that has the potential to be an absolutely fatal flaw. It certainly makes this author question if the technical and business justifications exist today for the expedient deployment of this new network standard.

Like most things in the world of electronics, the viability of the application eventually leads to power requirements and energy utilization. In most situations, these critical factors are not given serious, proper consideration until far too late in the deployment process, and 5G is no exception to that. The fatal flaw is that most of the folks in the information and communications technology ecosystem, from mobile network operators to those deploying edge devices, assume that a network and its supporting infrastructure (that is, the utility distribution network) is robust and ready to enable the many billions or trillions of devices and handle their power demand. There is an extreme disconnect in the realization of how

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Digital Object Identifier 10.1109/MPEL.2019.2947105
Date of current version: 17 December 2019

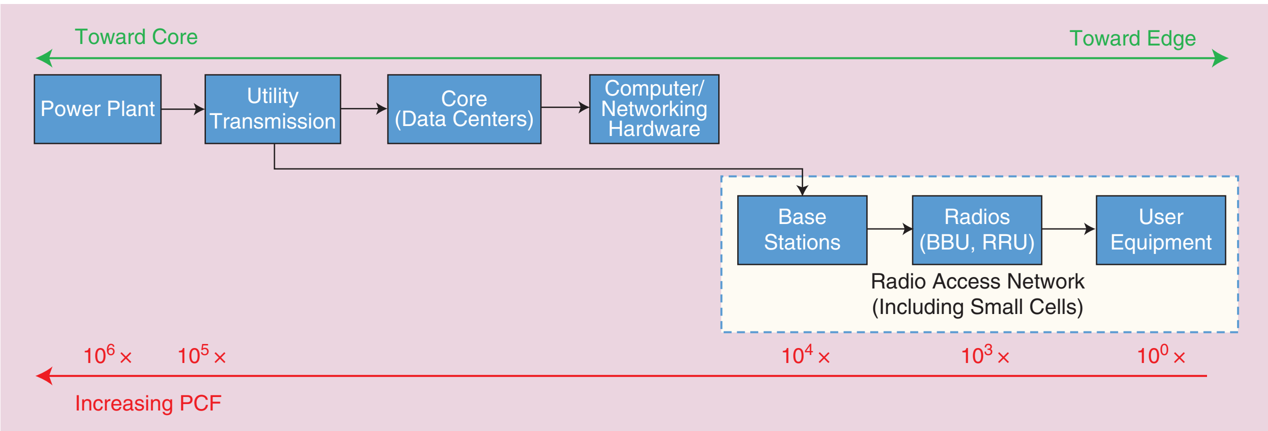

FIG 1 The PVC from the network edge to the power plant. BBU: baseband unit; RRU: remote radio unit. (Source: PowerRox; used with permission.)

much energy is required to supply edge devices. In fact, the farther a device or system is from the power plant and the closer it is to the edge, the higher the multiplication factor, also known as the power cost factor (PCF) of its energy requirements. Even a simple analysis shows us how microwatt-level devices can have a direct impact on the ability of the utility grid to meet the load energy requirements while maintaining reliability. This is what I refer to as the *5G Energy Gap*, and it is the single biggest risk to current 5G deployments [3]. In other words, microwatts are determining the fate of terawatts (that is, an 18-order-of-magnitude spectrum).

Let us take a step back to consider just how much power must be generated to support all of these relatively tiny devices at the edge of the network (the farthest endpoint from the core network, typically where most devices reside). To do this properly, we must follow the power from end to end in what I refer to as the *power value chain* (*PVC*), which represents the full conversion and distribution chain from generation to the end load (without considering power plant efficiency, which tends to be quite awful). Figure 1 shows a graphical representation of the PVC for a typical edge device (that is, a smartphone or user equipment) to the power plant. Now, just as a start, let us consider what the true cost of a single milliwatt is. In other words, how much power must be generated at the plant to source 1 mW of received power at the smartphone? Figure 2 breaks the PVC into the major components of power distribution, with estimates (minimum to maximum) of the loss for each stage.

Even through this simple exercise, one can see that anywhere from 18 to 60 W must be generated to have 1 mW of received power at the edge device. This is a PCF of ~18,000–60,000 for how much power must be generated to provide that single milliwatt [4]. It should be noted that this analysis does not include all of the energy required for processing data and other overhead factors. So, in reality, we are talking about PCFs that can be six or more orders of magnitude for 1 mW of instantaneous power. Now, multiply these energy requirements by how often a single device receives these power “packets” and multiply that by the many billions and even trillions of devices on the edge.

Fundamentally, this simple analysis shows how the sheer number of edge devices (regardless of their bandwidth requirements) plays a much bigger role in impacting the PVC and localized utility grid than the high-bandwidth, low-latency devices that seem to be the focus of most network architects, equipment makers, and those involved in deployment. In other words, all those things streaming videos or under real-time control (such as an industrial robot) may be consuming ≫90% of the network traffic, but they represent ≪5% of the number of devices (nodes, motes, things, and so on) deployed on global networks. Since >95% of them are low bandwidth and high latency, it is actually these relatively “slow” and “simple” devices (typically of the ultralow-power variety) that are truly determining the fate of 5G. This is the primary reason why energy harvesting technologies are a critical enabler for driving corrective action to this network-failure analysis [2]. Supplementing a relatively tiny bit of energy at the edge has the effective benefit of saving six or more orders of magnitude worth of power at the generating plant.

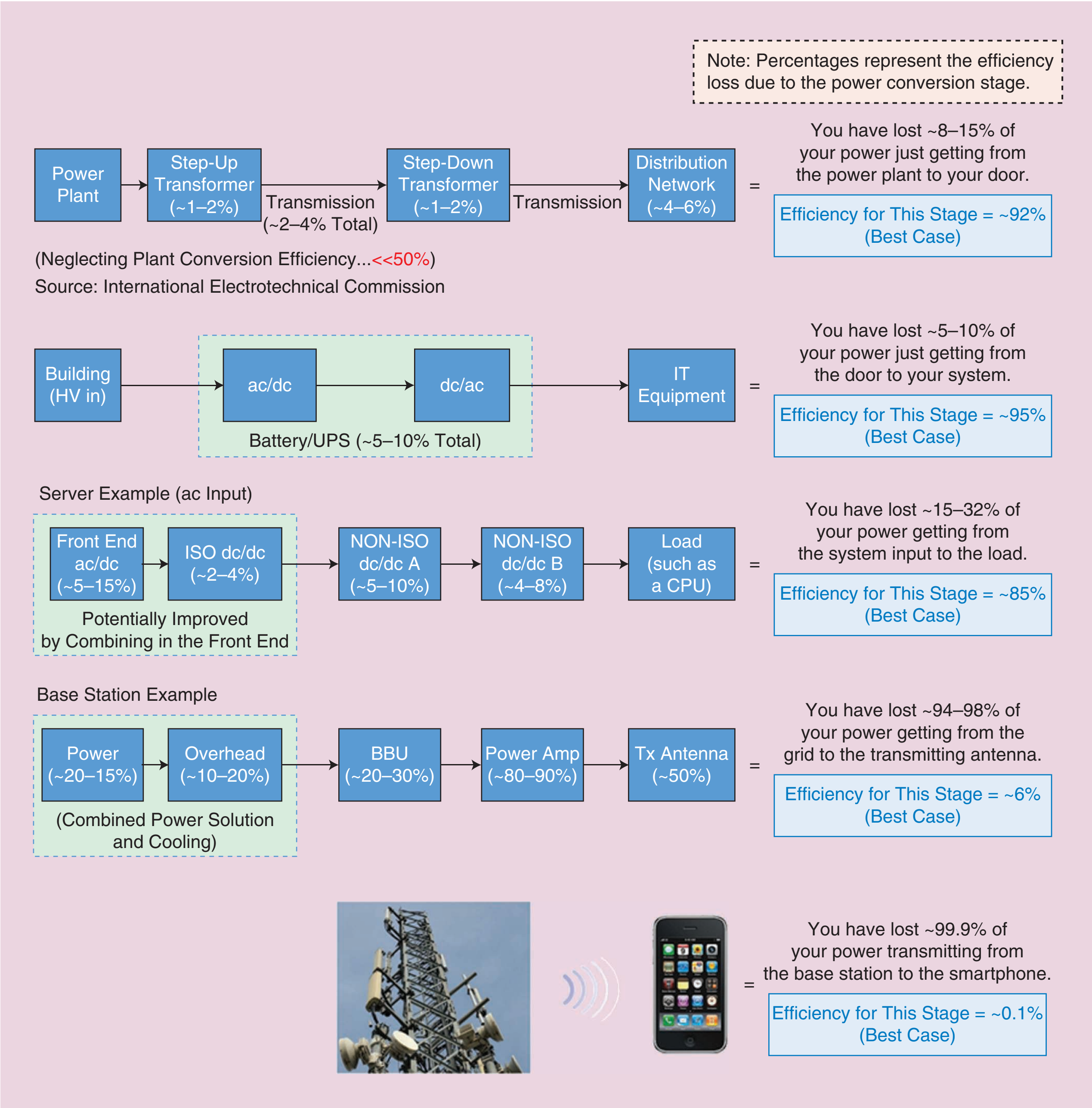

FIG 2 The PVC component efficiencies (worst to best estimates) at each stage. Amp: amplifier; HV: high voltage; ISO: International Organization for Standardization; Tx: transmitter. (Source: PowerRox; used with permission.)

If you are interested in learning more about the 5G Energy Gap, PVC, PCF, energy harvesting, and how they all come together to form the perfect storm, please consider getting involved in the newly launched Energy Efficiency Working Group of the IEEE Future Networks International Network Generations Roadmap. You can email 5GRM-Energy@ieee.org or visit https://futurenetworks.ieee.org/roadmap.

About the Author

Brian Zahnstecher (bz@powerrox.com) received his B.S. and M.E. degrees in engineering from Worcester Polytechnic Institute, Massachusetts. He is a principal at PowerRox, San Jose, California, a consulting company that focuses on power design and integration, system applications, original equipment manufacturer market penetration, market research/analysis, and private seminars for power electronics. He is a chair emeritus of the IEEE Power Electronics Society San Francisco Bay Area Chapter, which received the local, national, and worldwide Best Chapter Awards 2017, an unprecedented achievement. He leads the Energy Efficiency Working Group for the IEEE 5G Roadmap and authored the power position paper for the Applications and Services Working Group. He serves on the Power Sources Manufacturers Association (PSMA) Board of Directors and cochairs the PSMA Energy Harvesting Committee and Reliability Committee, which he cofounded. He contributes to the PSMA Power Technology Roadmap (2015, 2017, and 2019) and cochairs the 5G Webinar Series and First 5G Energy Efficiency Tutorial. He is a Senior Member of the IEEE.

References

[1] 3GPP, “3GPP release.” Accessed on: July 2, 2019. [Online]. Available: https://www.3gpp.org/specifications/releases

[2] B. Zahnstecher, “5G opens the door for energy harvesting (EH) in Telco Applications,” presented at Intelec 2017, Gold Coast, Australia, Oct. 22, 2017.

[3] B. Zahnstecher, “Powering 5G: Moving utilization to data center or the edge,” presented at Intelec 2016, Austin, TX, Oct. 23, 2016.

[4] B. Zahnstecher, “Reducing base station power–A key enabler for 5G,” presented at Intelec 2018, Torino, Italy, Oct. 7, 2018.

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