Power Electronics

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Abstract

The IEEE 5G Initiative Roadmap [1] effort is a collaboration to assist in bringing clarity and direction to a highly convoluted soup of leading-edge technologies. This paper focuses on the power electronics, power utilization, and power architecting aspects of 5G enabling technologies. With so many of these technologies highlighted here, a reader shall be reminded that this discussion focuses on power and how said technologies can be improved and optimized for minimal power utilization. This may involve design techniques, intelligent network utilization, intelligent component utilization, and end-user education.

1. Introduction

We have all seen plenty of the marketing hype for what will eventually become 5G in the ~2020 production deployment timeframe. At multiple industry events, we have spent the last couple years trying to shed light on the most critical aspects of the network (from architecture to utilization), which dictate the paradigm shifts in power electronics and power utilization required to enable 5G [2]. “*Abstraction*” and “*Disaggregation*” are terms that have frequent, thematic regularity coming to mind in the analyses of power utilization and power architectures related to these paradigm shifts. From data centers to base stations, network constituents will be decomposed from the larger, centralized solutions of yesterday to modular components sized to more local application requirements. Peak shaving techniques with local energy storage have been demonstrated to ensure network stability and continuity of Quality of Service (QoS), while enabling the overall power architecture to be designed around average power draw, thus alleviating a lot of overdesign and overprovisioning. These strategies shall yield significant power savings by enabling agility for dynamic, real-time network traffic shifts (beyond pattern-based predictions) and optimization of the real-time power markets, while providing flexibility and reducing capital & operational expenses (CAPEX & OPEX) at the same time.

2. A Paradigm Shift in Telecom / Network Power

5G presents a complete infrastructure change in telecommunications and data transfer that must be carefully architected at every point in the network from the telecom data centers all the way down to the edge, where it touches the average consumer. Along the way comes a host of challenges in Software-Defined Networking (SDN) / Network Function Virtualization (NFV), fat data aggregation backbones, and self-organizing edge networks that will consist of massive multi-input multi output (mMIMO) phased antenna arrays all working together to provide unprecedented bandwidth and latencies to the end-user in the 10s of GHz of radio frequency (RF) spectrum. Let us not forget that low-bandwidth, low-latency applications such as Internet of Things (IoT) / Industrial IoT (IIoT) devices and wireless sensor networks (WSN) are also expected to make a significant contribution (perhaps even rivalling the streaming video that seems to drive most focus in this area) to overall network traffic and should be considered accordingly. Ironically, it may be the lowest-power components that drive overall consumption due to the momentum of volumes.

This complicated, multifaceted network can only be successful through the utilization of many power optimization and Intelligent Power Management (IPM) techniques. In the data center [3], the high degree of hardware (HW) and software (SW) hooks that exist in modern computing/networking equipment allow for telemetry, dynamic power throttling/sharing, and peak demand needs to be met through a marriage of all these technologies. Even at the edge-device-level (i.e. – smartphones, IoT devices, etc.), careful power architecting and IPM will dictate how efficiently data can be received and processed. Given the large number of wearable and IoT devices that are predicted to be in every home around the time the official 5G standard is scheduled to go into production ~2020, edge processing and buffering will be key enablers to the realization of this network for all.

With ~90% of all power in a cellular network consumed by base stations and ~60-80% of that base station power consumed by the power amplifiers (PA), it seems the PA is the best place to start and provides the best “low-hanging fruit” opportunity for optimization efforts [4]. Clever management of the RF PAs used in transceivers on the cell towers and in handheld devices are essential to the success of this incredible technology deployment. RF spectral efficiency optimization techniques such as Beam Forming (> 6 GHz) and Spatial Multiplexing (< 6 GHz) are promising to enhance directed energy transfer between source and recipient. Given that analog-to-digital converters (ADC) consume a large chunk of base station power, there is much value in considering the tradeoff between number of ADC bits and bit acquisition frequencies. For instance, it has been demonstrated that increasing the number of bits causes an exponential increase in ADC power, while increasing acquisition rate increases power utilization linearly. Therefore, it could be acceptable to have as little as a single-bit ADC operating at a very high acquisition rate to meet network specifications and save a significant amount of power [5] in the overwhelmingly largest slice of the power pie for the entire network! Other techniques implemented directly in the power electronics, such as envelope tracking PAs, build upon technologies deployed for 4G-LTE and optimize the savings for 5G.

Though not a major area of focus, energy harvesting (EH) presents a host of interesting and useful applications that can be utilized today as well as provide a roadmap for enhancing/increasing application use cases moving forward. From mW to MW, there are scalable EH technologies to take advantage of nearly every energy source physics affords us (i.e. – kinetic, thermal, RF, photovoltaic, piezoelectric, vibrational, etc.). The major shift from macro towers to heterogeneous networks (HetNets) of many small cells makes 5G an ideal candidate for EH applications. As we go from Macro Cells to Femto cells & Atto Cells (perhaps Zepto Cells?!?), the power budgets go from kilowatts to tens of watts to <<1W. The smaller the budget, the better the opportunity for scavenging ambient energy. Battery mitigation [6] is a key goal of EH technology initially by supplementing battery power to extend battery life [7] and eventually disposing of them altogether. Even security at many network points from the base station to the grid-level can benefit from EH by achieving grid independence/redundancy and/or inhibiting undesired network penetration.

3. Conclusion

In summary, the 5G network is rife with opportunity for reducing power utilization in applications that have a significant impact on the global power footprint. Applying "economies of scale" to the optimization techniques in these high-visibility applications shall also yield tremendous benefit as they are demonstrated as viable and trickle down to many other applications and markets in the world of electronics. The IEEE has been a long-time leader in driving solutions for the planet and the mammoth initiative of 5G will be another feather in a very full cap.

For questions/comments, feel free to contact Brian Zahnstecher at bz@powerrox.com.

References

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