Poster: Characterizing Performance and Power for mmWave 5G on Commodity Smartphones

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ABSTRACT

During the first half of this year, three major operators in the US have announced their 5G deployment, which indicates the advent of next generation networks. To reduce the time to market, carriers utilize 5G NR[1] for data plane operations while retaining the existing 4G infrastructure for control plane operations in what is called NSA (Non-Standalone) deployment mode defined as 5G system Phase I. EN-DC[2] is a core technology of NSA 5G which supports the introduction of 5G services under 4G infrastructure [1]. It enables a UE to connect to LTE and NR at the same time whereas the control plane connection is handled by LTE infrastructure. In this case, the UE will have only one single RRC state machine. Note that LTE RRC state machine contains RRC_CONNECTED and RRC_IDLE with different DRX settings while NR RRC has an additional state called RRC_INACTIVE [2].

In this work, we aim to explore network and power characteristics for NSA 5G which introduces a surprisingly high data rate. To achieve this goal and unveil potential issues in 4G-5G interworking, we are faced with numerous challenges:

- It remains unexplored whether carriers are applying the same RRC state machine as 4G studied in [3] or its NR version and how users are benefiting from the dual connectivity.
- NSA 5G adopts LTE control plane and NR data plane. How does each part contribute to the power consumption and performance under diverse scenarios (*e.g.*, standby, handover, low-rate streaming, bulk transfer)?
- There are a large number of environmental factors that may affect 5G power consumption (*e.g.*, LoS/NLoS, weather, distance to tower, orientation). How to systematically explore such large space and quantitatively identify key factors?

We propose the following steps to address the challenges:

Network-based NR Parameter Inference. Carriers may configure their own state machines with varied parameters. Thus an accurate inference is needed for performance characterization. By monitoring the current network type, we can check when the device is using LTE/NR. We strategically adjust the packet dynamics between devices to trigger different RRC states and compute transition timers using collected RTTs since RTT varies as the packet interval changes.

5G Power Model Construction. Using a power monitor, we measure the energy consumption for each state. Before each experiment, we wait for sufficient time to ensure the device is in RRC_IDLE (this state can also be set as baseline). We keep a 5G connection and collect power traces containing timestamps and instant power values. As different states have different energy consumption levels, we can derive the power model by calculating the average power of each state. We will validate the power model by comparing measured energy with simulated energy for apps. Meanwhile, the model can help to validate our network-based inference results.

Impact of Network Components. As the NSA 5G uses LTE control plane and NR data plane, each component may contribute differently to the power consumption and performance. With inferred network parameters and power model, we can look into them under different network scenarios (*e.g.*, standby, handover, data transfer) by breaking down 5G energy consumption and comparing with those in 4G.

Analysis on Environmental Factors. We further study real-world factors that may affect power consumption. We perform the same network activities from basic tasks (bulk transfer) to real applications (UHD video streaming), under various environmental conditions (*e.g.*, LoS/NLoS, weather, distance to base station). In addition to throughput and app QoE, we investigate energy consumption for each activity.

[1]New Radio
[2]E-UTRAN New Radio - Dual Connectivity

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