Telemetry-Driven Protocol and Application Optimization for Next Generation Networks

As an infrastructure, the performance of the 5G network itself remains mysterious and largely unexplored. Performing network measurement inside a proprietary commercial network, especially inside the RAN, is however challenging, since it usually requires cooperation from the service provider to deploy either hardware or software inside the network. This lack of visibility hinders our ability to study interactions between 5G, and the upper transport layer and applications, ultimately limiting optimization efforts.

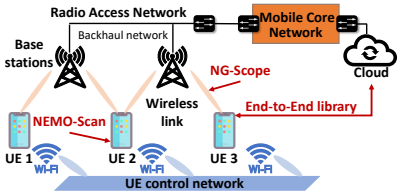

Figure 1: The architecture of network-wide telemetry system, which includes NG-Scope, NEMO-Scan, an end-to-end measurement library, and a UE control network.

In this research, we propose three research tasks: *comprehensive 5G telemetry system*, where we develop a telemetry system to perform large-scale measurements to understand the internal workflow of the proprietary commercial cellular network without any cooperation from the server provider, unlocking unprecedented insights; *cellular protocol performance diagnosing*, where we examine the internal behavior of the cellular networks protocol stack using our telemetry system, open the black box of the internal algorithms implementation, pinpoint any possible performance bottlenecks and propose corresponding solutions; *Cellular-Aware Transport Layer and Application*, where we study the interactions between cellular protocol and the upper transport layer and applications. Based on our understanding, we propose to optimize the transport layer protocols, such as the congestion control, and the applications for maximum performance inside cellular network.

Trust 1—Cellular Telemetry System. We have developed NG-Scope, a cellular monitoring tool that observes the air interface between base stations and associated UEs (see Figure 1). Additionally, we are building NEMO-Scan to extract essential debug information from cellular modems and analyze the extensive message exchange between UEs and base stations. NEMO-Scan surpasses the capabilities of prior work like MobileInsight by providing richer insights into 4G LTE devices and, crucially, supporting 5G phones to uncover 5G-specific messaging. We are also creating an end-to-end measurement library for controlled assessment of key metrics like delay, loss, and jitter. Our vision is to integrate NG-Scope, NEMO-Scan, and this measurement library into a large-scale telemetry system (Figure 1). We plan to strategically deploy UEs across a wide area, establishing a separate control network via non-cellular interfaces (e.g., Wi-Fi). This control network will enable coordinated, network-wide measurements at an unprecedented scale.

Trust 2—Cellular Protocol Diagnosing. While 3GPP standards provide the 5G framework, they leave flexibility in scheduling algorithm implementation for manufacturers and operators. This includes critical areas like resource allocation (uplink/downlink), carrier aggregation/dual connection management, and dynamic 4G/5G spectrum sharing. Our extensive measurements have exposed significant performance issues in current resource allocation implementations—namely, increased delay and delay variation that negatively impact upper-layer applications. We propose to use in-depth measurements to reverse-engineer these vendor-specific implementations, pinpoint the exact sources of performance bottlenecks, and develop targeted solutions.

Trust 3—Cellular-Aware Transport Layer and Application. We have demonstrated the power of cellular-awareness with PBE-CC, our LTE congestion control algorithm developed using NG-Scope. Building on this success, we propose two key research directions. *Cellular-Aware Design.* Our telemetry system will provide unprecedented insight into interactions between cellular protocols, transport layers, and applications. This knowledge will drive a fundamental redesign, making these elements truly optimized for cellular environments. *Real-time Cross-Layer Optimization.* Our telemetry system's ability to deliver real-time, cross-layer information opens the door for innovative cellular-aware transport and application designs.