

Addressing QoE Measurement Challenges for the Mobile Internet

Z. Morley Mao (zmao@umich.edu)

QoE issues associated with the mobile Internet are arguably a superset of the challenges of the Internet QoE, as the end to end mobile Internet path is composed of the radio wireless network hop, followed by the wireless core network path (e.g., the core cellular backbone) and the subsequent Internet component. We argue that to address the QoE measurement challenges, we must consider the cross-layer interaction across the radio layer, IP layer, transport layer, and the application layer. Given the more constrained radio network resources and the circuit-switched nature of the radio resource allocation, the Mobile Internet imposes some unique new challenges beyond the typical performance metrics, such as energy efficiency issues. Furthermore, the QoE metrics should consider the UI interaction with the user, which is far more diverse for mobile platforms compared to desktop settings. We propose the following initial principles for QoE characterization for mobile Internet.

Consideration of cross-layer interaction: We have shown in our prior work [1] that cross-layer interaction (e.g., radio layer failures that lead to TCP retransmission time-out) for mobile applications can lead to performance degradation. To more deeply analyze the QoE measurement results, our proposed analyzer [1] supports cross-layer mapping between the UI layer and the transport/network layer, and between the transport/network layer and the RRC/RLC layer. This allows us to better understand how user actions in the UI layer are delayed by the network traffic, and helps us identify the potential bottleneck in the cellular radio link layer that limits the TCP/IP data transmission speed. The cross-layer visibility is critical to understand the underlying reasons for observed performance degradation. An example of the importance of the cross-layer analysis is demonstrated in our previous work [2] where we showed that RRC state machine transitions can lead to serious delays (e.g., several seconds) on the critical path of a mobile network application operation.

Energy or data usage efficiency at the same importance as performance: Mobile users often have limited data usage and constrained battery resources; thus, the QoE experience should include metrics of energy efficiency and data usage. Better performance may not directly translate to lower energy or data usage because of the overhead of sending data possibly using multiple network interfaces. The tradeoffs between energy efficiency or data usage and performance should be evaluated to balance these potentially conflicting objectives to achieve optimal user experiences. Our prior work [3] focuses on understanding the power profile of the cellular network interface. Such analysis can be used to analyze the performance and energy characteristics of mobile applications.

Context-aware measurement support: Because of the variable nature of the wireless network, it is important to capture the context associated with each measurement. Such context includes important information such as signal strength, network location, RRC state or wireless network state, which directly influence the perceived user QoE. Understand the influence of such

context requires precise context-triggered measurement support, which we have developed in our Mobilyzer open measurement platform for controllable mobile network measurements [4][5]. Such measurement support is a basic building block enabling more complex and programmable measurement capabilities. For example, to understand how handover impacts user experiences require an accurate way to capture the handover events and issue measurements at the same time to identify the correlation. In our initial findings, We focus on handover between WiFi and cellular networks, Inter-Radio Access Technology (IRAT) handovers in cellular networks, and handovers between cells within the same cellular network. We find that interruption in connectivity for horizontal handover is minimal, but the current handover strategy is suboptimal in terms of end-to-end performance due to the use of signal strength to make decisions, which is an imperfect metric for performance. The strategy for vertical handovers makes decision on network type regardless of performance, which can cause link failure, greatly degrading user's experience.

Application-specific QoE metrics: Mobile network apps are rather diverse in the UI design and the resource usage. It's thus necessary to develop application-specific QoE metrics that capture the main classes of apps of interest, e.g., interactive video, Web browsing, video streaming. In our most recent work of diagnosing VoLTE performance and reliability problems in collaboration with a cellular ISP [6], we developed an on-device audio quality monitor to help capture the voice problems directly experienced by end users. This also illustrates the importance of performing QoE measurements at end-points in addition to in-network measurements to understand the user-perceived performance.

References

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