Abstract

The extensive proliferation of 5G technology and the widespread adoption of massive Internet of Things (IoTs) applications contribute to the significant growth of mobile traffic. This surge necessitates network densification, leading to heightened energy consumption and operational costs for Mobile Network Operators (MNOs), thereby posing sustainability challenges. Moreover, the increase in data demand, pushed by the popularity of communication services, poses a challenge for bridging the digital divide and foster ease of reach over a cost-effective network.

Aligned with this objective, this thesis significantly contributes by exploring the potential of Advanced Sleep Modes (ASMs) in diverse 5G scenarios and traffic conditions. Furthermore, we investigated efficient communication methodologies, by leveraging edge caching and a recommendation system atop Power Line Communication (PLC) networks. This multifaceted approach aims to extend Information and Communication Technology (ICT) services to remote areas, addressing the digital divide.

Base Stations (BSs) constitute 80% of the overall Radio Access Network (RAN) consumption, and their energy requirements are projected to increase due to the anticipated surge in mobile data traffic in the coming years. In response, 5G BSs integrate ASMs during periods of low traffic, gradually deactivating BSs into deeper sleep modes with lower power consumption. However, the use of deep sleep modes introduces significant reactivation delays, posing potential challenges to Quality of Service (QoS). Recognizing the scenario and load-dependent nature of optimal configuration settings, we propose a framework based on a stochastic model for dynamically tuning configuration settings in real-time, adapting parameters to the actual traffic load and scenario. 5G has different latency requirements for URLLC (Ultra-Reliable Low-Latency Communication) and eMBB (enhanced Mobile Broadband). To auto tune parameters associated with ASMs according to the delay specification, we formulated and validated a closed form analytical approach; DCASM (Delay Conservative Advanced Sleep Mode). This adaptive approach seeks to fulfill a predetermined constraint on the average BS reactivation delay. Nevertheless, knowing the overall traffic pattern and the accuracy of traffic predictions is eminent to achieve the desired performance in RAN with DCASMs. Therefore, we simulated the DCASM approach over the traffic prediction to carefully analyze the impact of error in the prediction.

Besides achieving the sustainable communication for 5G RAN, in the context of advancing from 5G to 6G and expanding ICT services, our thesis addresses the challenge of bridging the digital divide and providing connectivity to remote areas. We propose a collaborative caching scheme over PLC to efficiently offer connectivity and content services by leveraging existing infrastructure. The primary objective is to enhance connectivity and content accessibility in these areas. Beyond conceptualizing the model, we develop a mathematical framework to analyze average download delays, validated through simulations. Initially, we employ a Zipf distribution as a content demand model, subsequently testing various popularity models to assess the impact of dynamic content popularity on the Cache Hit Ratio. To optimize the system further, we introduce a recommendation system, redirecting from the bottleneck link to the cloud and enhancing the collaborative caching system's efficiency. The results exhibit promising performance improvements, particularly enhancing the capabilities of limited capacity PLC links.