Performance Evaluation of 5G/Wi-Fi Offloading Mechanisms in High-Traffic Urban Environment

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Abstract— **Traffic offloading in 5G networks enables the redirection of specific data flows from the cellular core and backbone to alternative access paths such as Wi-Fi edge nodes. This reduces network congestion, enhances cell-edge coverage, improves quality of service (QoS), and lowers operational costs. 5G Wi-Fi offloading leverages the unlicensed spectrum to provide additional capacity and mitigate data bottlenecks. As 5G deployment expands, Wi-Fi's ubiquitous coverage and cost efficiency make it an integral component of mobile network strategies. Recent advances such as LTE-U and Licensed Assisted Access (LAA) facilitate cellular/Wi-Fi coexistence in the 5 GHz band through Carrier Sense Adaptive Transmission (CSAT), standardized in 3GPP Releases 12 and 14. Properly managed offloading delivers seamless and cost-effective connectivity. Considering millimeter-wave (mmWave) penetration challenges, Wi-Fi deployment is essential for extending indoor and edge coverage. Furthermore, the rapid growth of machine-to-machine (M2M) and massive machine-type communication (mMTC) in 5G emphasizes the need for continuous connectivity. As smart city and IoT initiatives expand, Wi-Fi offloading has become a key enabler of 5G networks. In a real-world deployment test conducted in the high-traffic area around Sukhbaatar Square, Ulaanbaatar, offloading within a 5G/Wi-Fi HetNet environment reduced the 5G sector load from approximately 90% to 65%, while Wi-Fi channel utilization increased from 40% to 65%. The average QoS index improved from 0.42 to 0.71, and Voice-over-IP (MOS) quality increased from 3.2 to 4.1, demonstrating the effectiveness of intelligent traffic offloading in enhancing user experience and network efficiency.**

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