RRC STATE TRANSITION SIMULATION: IDLE, CONNECTED, AND INACTIVE MODES IN 5G

The RRC Inactive state is an intermediate operational mode introduced in 5G New Radio (NR) networks. It was designed to address the limitations of the traditional binary model (Idle vs. Connected) used in LTE, which is inefficient for modern traffic patterns like intermittent IoT data.

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INTRODUCTION

The paper addresses energy inefficiencies in 5G networks caused by static RRC timers, particularly for sporadic IoT traffic. It proposes a real-time simulation framework featuring an "Adaptive Inactivity Timer" to dynamically adjust transitions to the RRC Inactive state, optimizing energy consumption while maintaining low latency.

OBJECTIVE

To develop a real-time 5G RRC state machine simulation framework that integrates an Adaptive Inactivity Timer (AIT) to analyze and optimize energy efficiency, latency, and signaling overhead across diverse traffic profiles.

METHODOLOGY

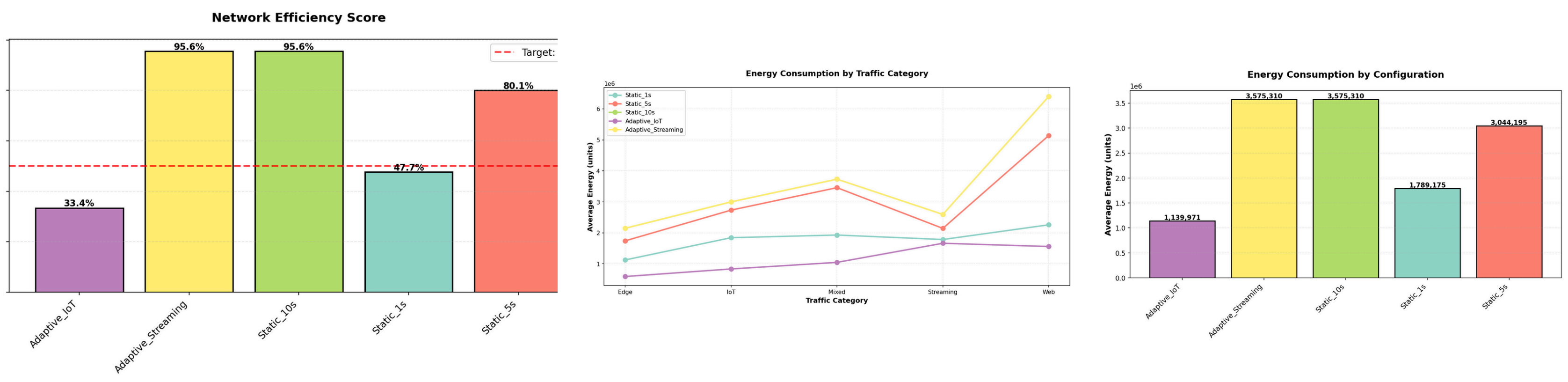
Using MATLAB Simulink and Stateflow, the study modeled 5G RRC transitions between Idle, Connected, and Inactive states. A novel Adaptive Inactivity Timer (AIT) was implemented to dynamically adjust thresholds based on traffic. The framework included real-time energy monitoring and an interactive GUI for performance evaluation.

RESULTS

The simulation demonstrated that the Adaptive IoT configuration achieved the lowest energy consumption by optimizing transitions to the RRC Inactive state for bursty traffic. Although this increased state transitions, it minimized energy waste compared to static timers, which often led to higher power usage and variability.

ANALYSIS

The analysis confirms that the Adaptive IoT configuration achieves the lowest energy consumption (~1.14M units) by aggressively utilizing the Inactive state, evidenced by its high transition frequency (24.9). Conversely, Static and Streaming profiles consume significantly more power (~3.58M units) due to prolonged connectivity, proving that dynamic switching optimizes energy efficiency.



CONCLUSION

This work validates the 5G RRC Inactive state as essential for energy efficiency. By implementing an Adaptive Inactivity Timer, the study demonstrated that dynamic state transitions significantly reduce power consumption for IoT devices compared to static timers, effectively balancing energy savings with network responsiveness.

Related literature

Energy Optimization for Mobile Applications by Exploiting 5G Inactive State
Authors: Liu & Kung, 2024
Predictive Modeling of RRC Inactive Transitions
Authors: Polaganga & Liang, 2024
Optimizing RRC State Transitions for Machine Type Communications
Authors::Zhang et al., 2023
Towards Energy Efficient RAN: From Industry Standards to Trending Practice
Authors: Kundu & Lin, 2024
Signaling Overhead Analysis of RRC Inactive State
Authors: Chen & Wu, 2023