EcoCell: Energy Conservation through Traffic Shaping in Cellular RANs

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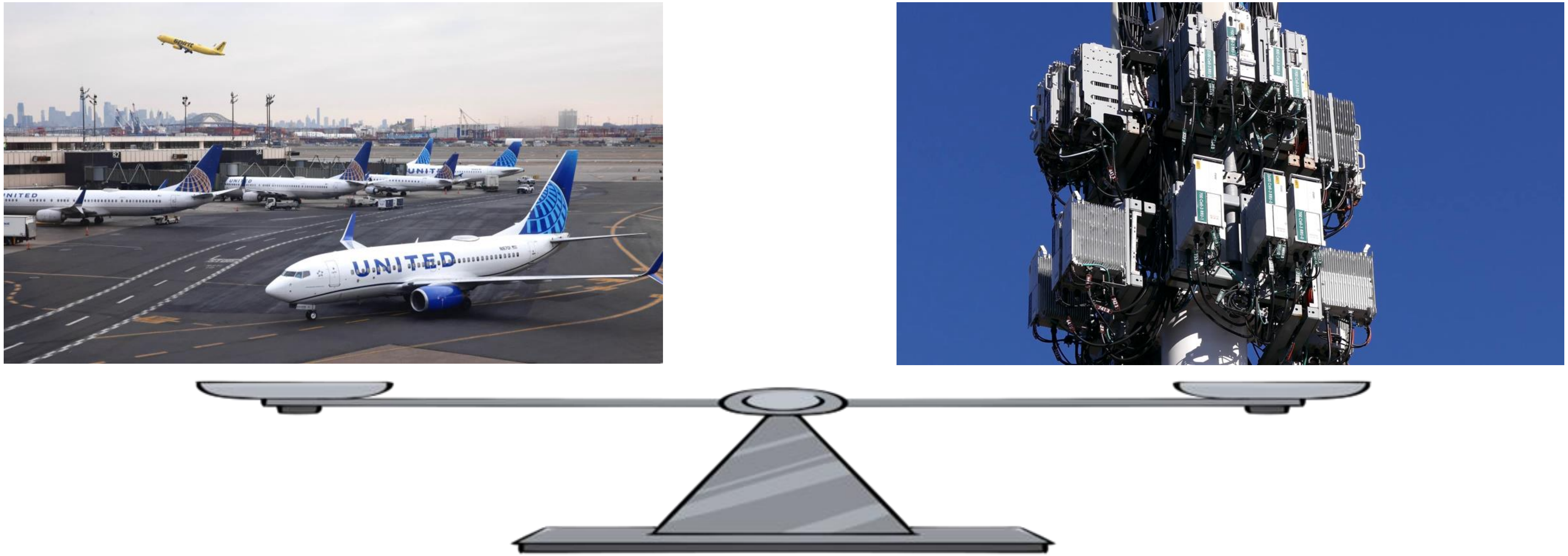
Cellular Networks Contribute Significantly to Carbon Emissions

- Carbon footprint of Telecom: 1.6%, comparable to aviation industry*
- ~6 million LTE Base stations worldwide, ~30tons of CO_2 per year



* L. Williams, B. K. Sovacool, and T. J. Foxon. The energy use implications of 5g: Reviewing whole network operational energy, embodied energy, and indirect effects. Renewable and Sustainable Energy Reviews

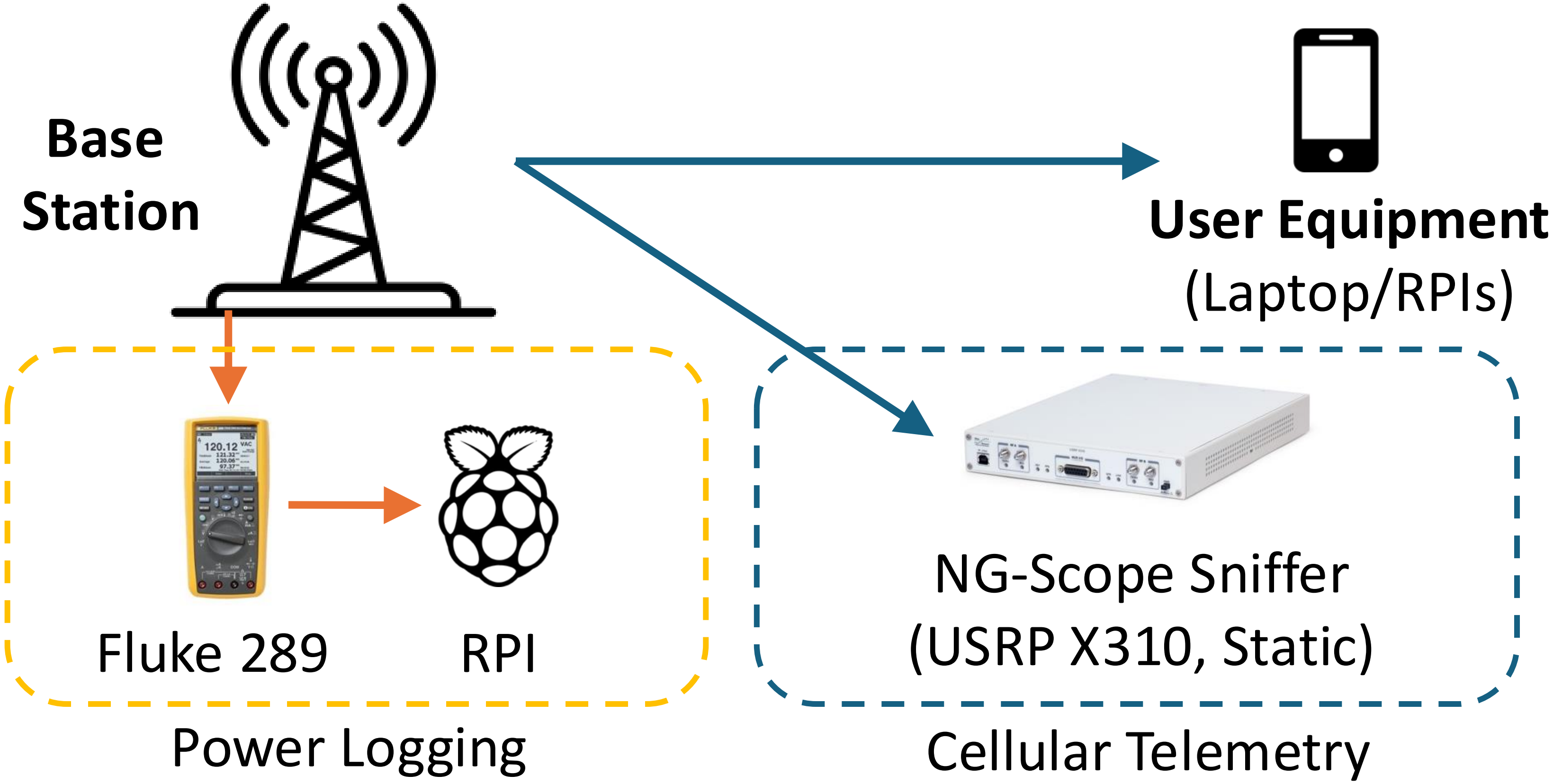
Existing Approaches

- **Hardware improvements:** more efficient power amplifier/cooling
- **Vendor side changes:** sleep modes or dynamic sector selection

Can we reduce the energy consumption of cellular infrastructures without any HW or vendor-side changes?

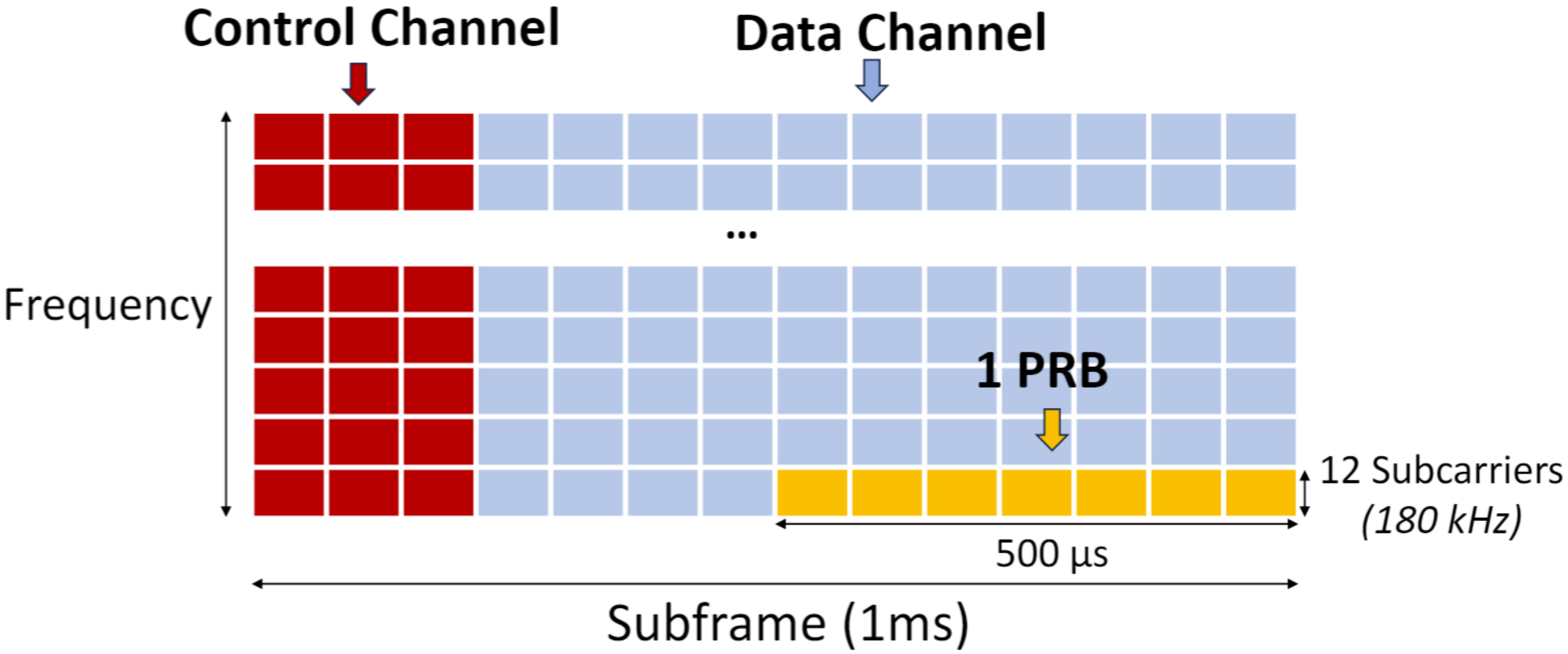
What are **energy savings opportunities** in **cellular base stations** at the scheduling layer?

We Identify Energy Saving Opportunities in Cellular RAN

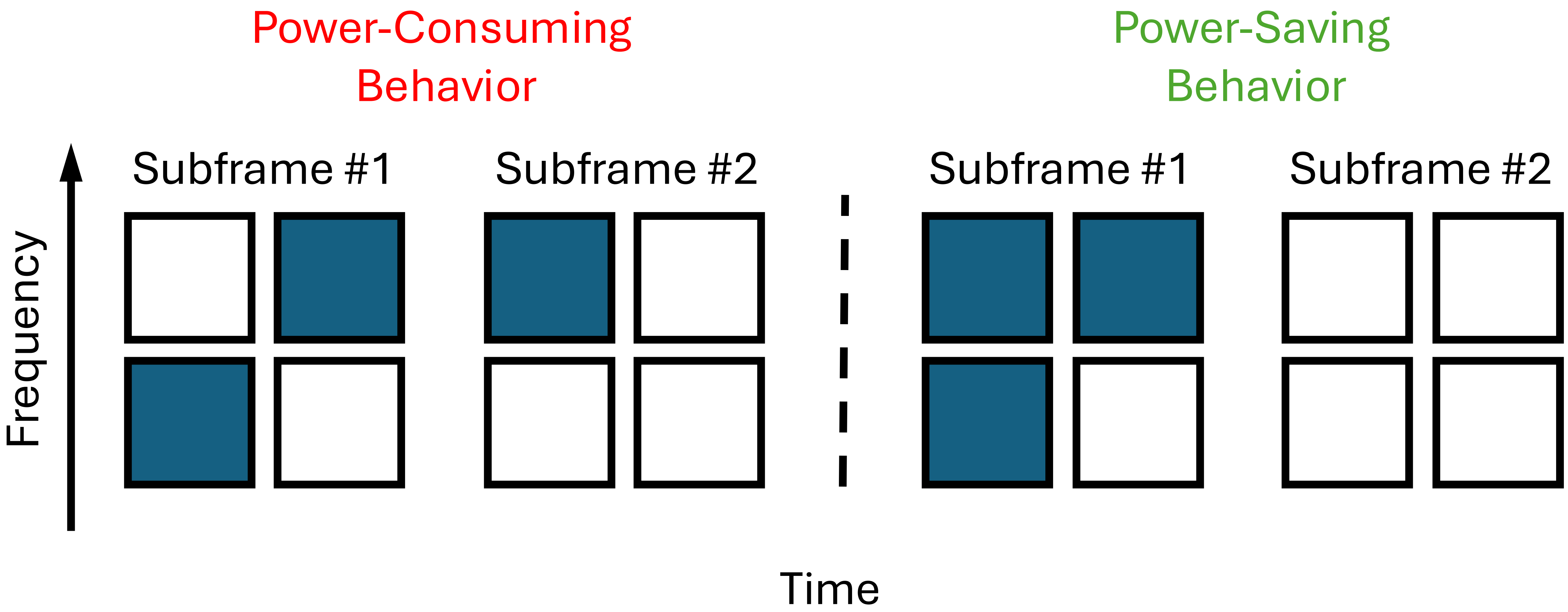


Energy scales with “*extra work*” per delivered bit

Background: LTE Subframe Structure

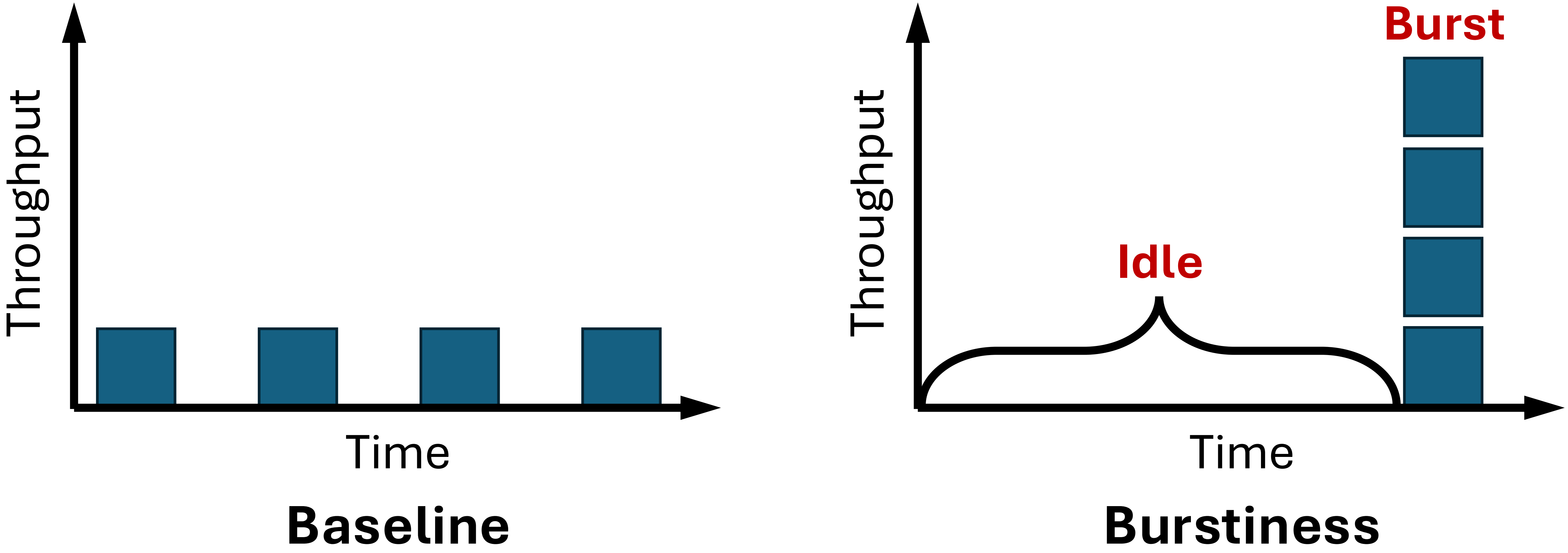


Observation 1: Packing Data in Fewer Subframes Saves Energy



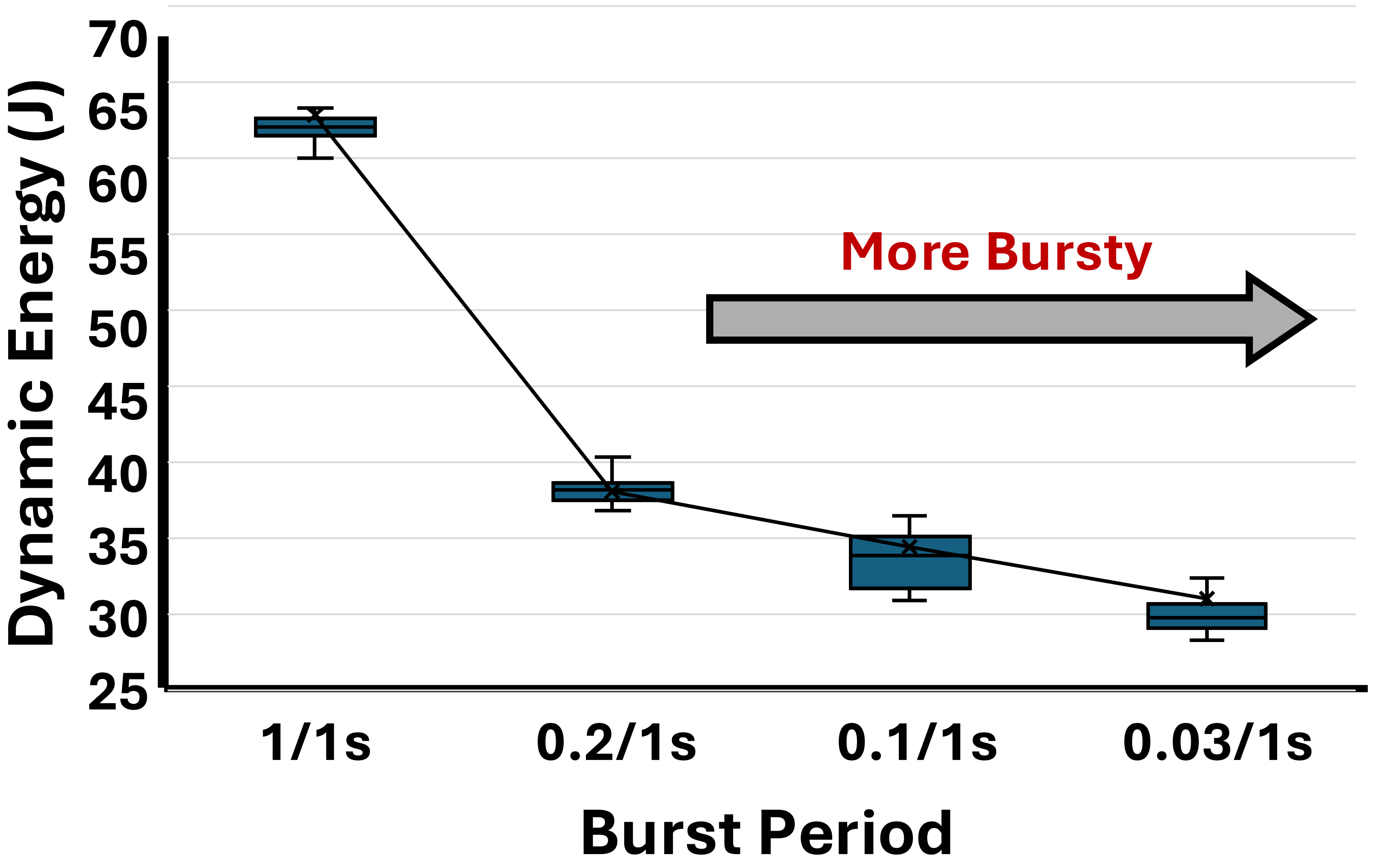
More subframes → More control overhead

Idea: Add Burstiness to Pack Data in Fewer Subframes



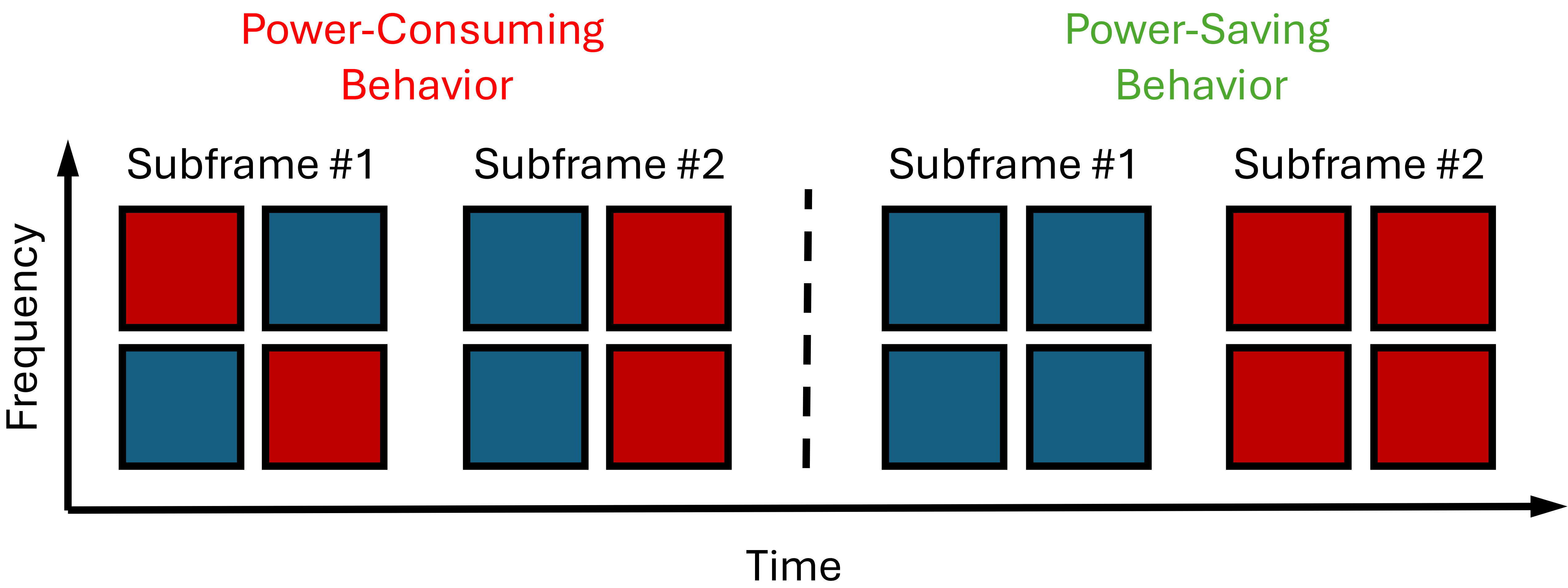
Same data → baseline spreads it across many subframes;
bursting packs it into few subframes

Microbenchmark: More Bursty → More Energy Savings



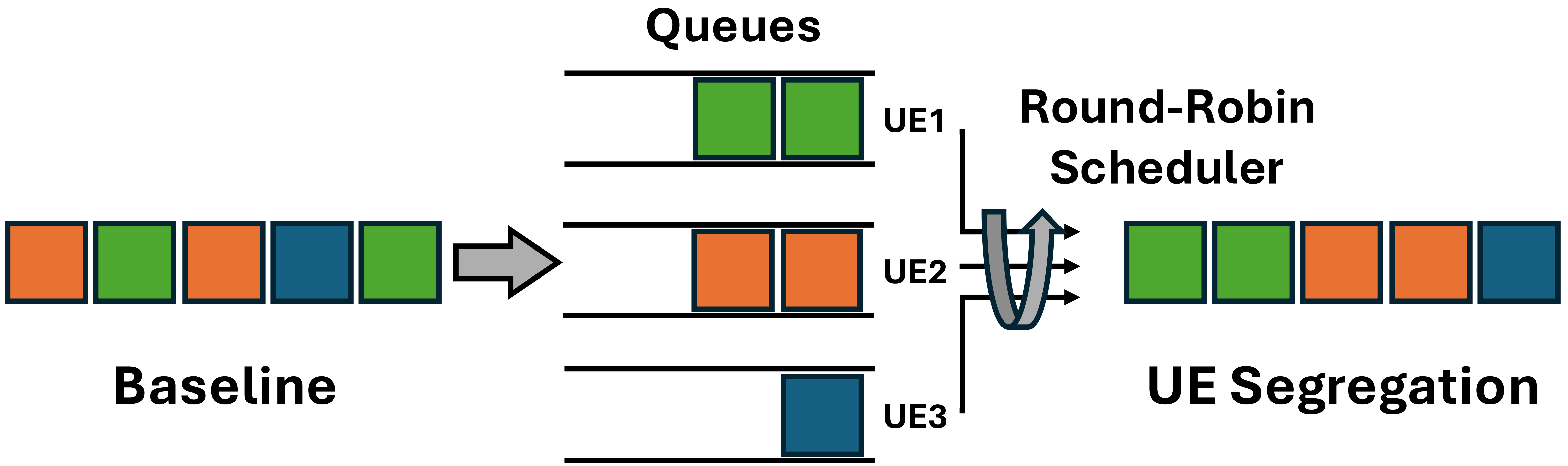
Bursty transmissions reduce base-station energy

Observation 2: Reducing # of UEs per Subframe Saves Energy



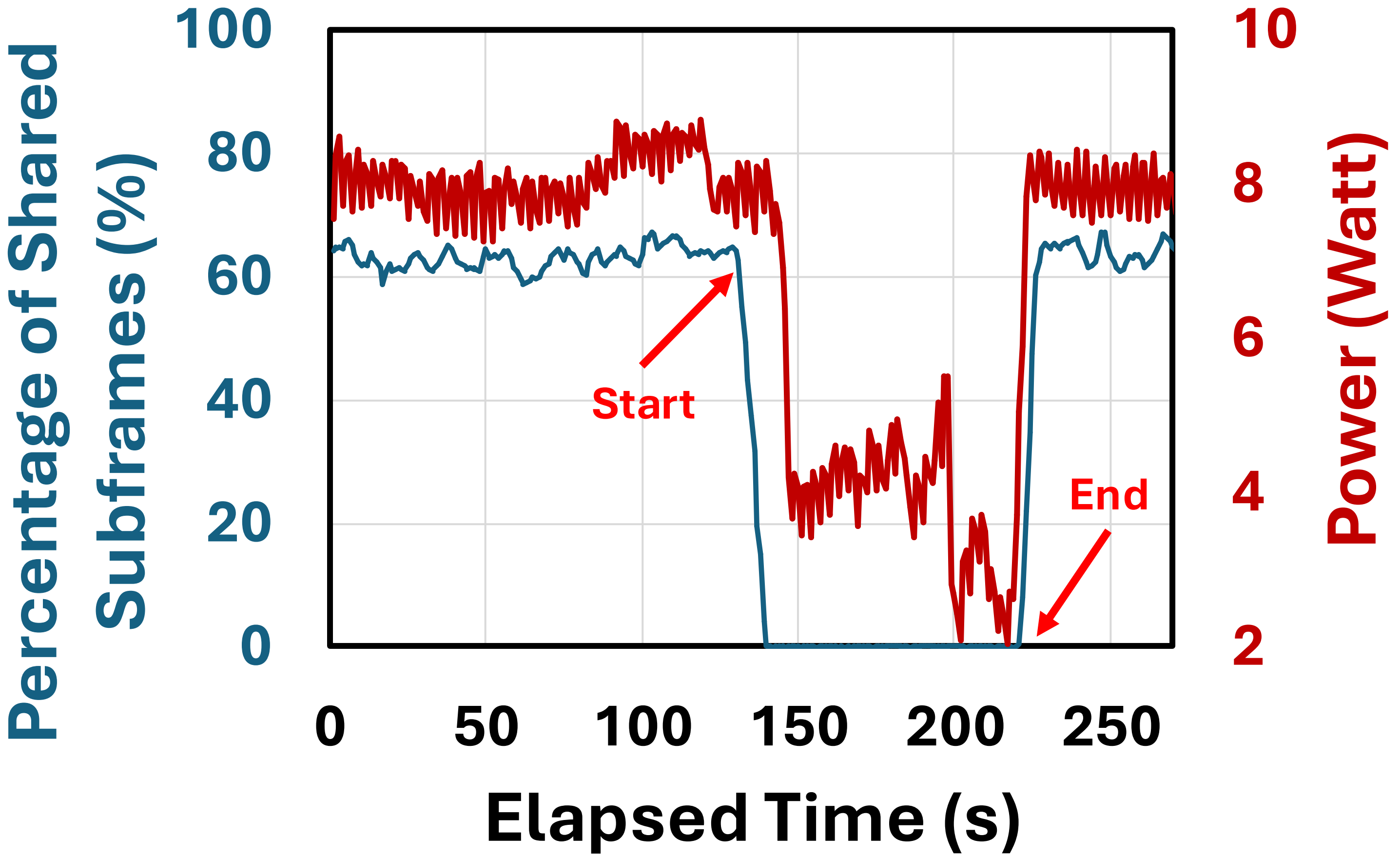
More UEs per subframe → More control overhead

Idea: Reorder Egress so Data from the Same UE Arrive Together



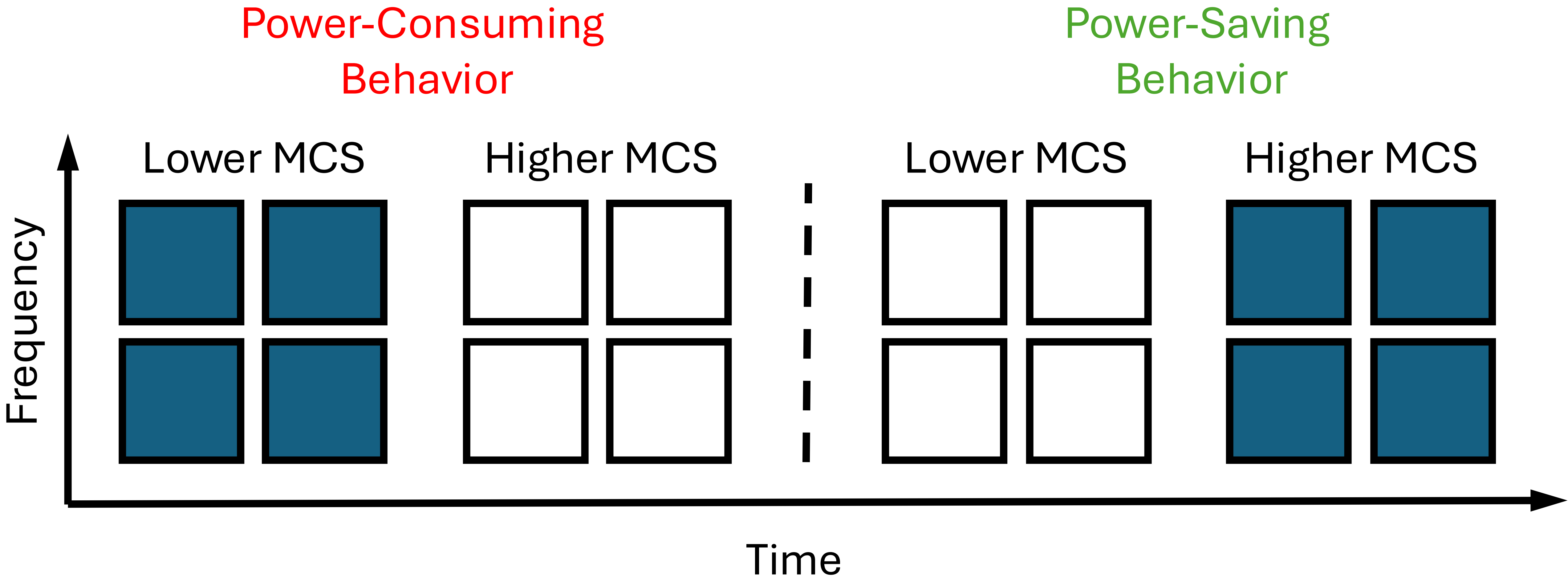
Same data → baseline's subframes contain data from diverse UEs;
segregation makes each subframe have less # of UEs

Microbenchmark: Less Sharing → More Energy Savings



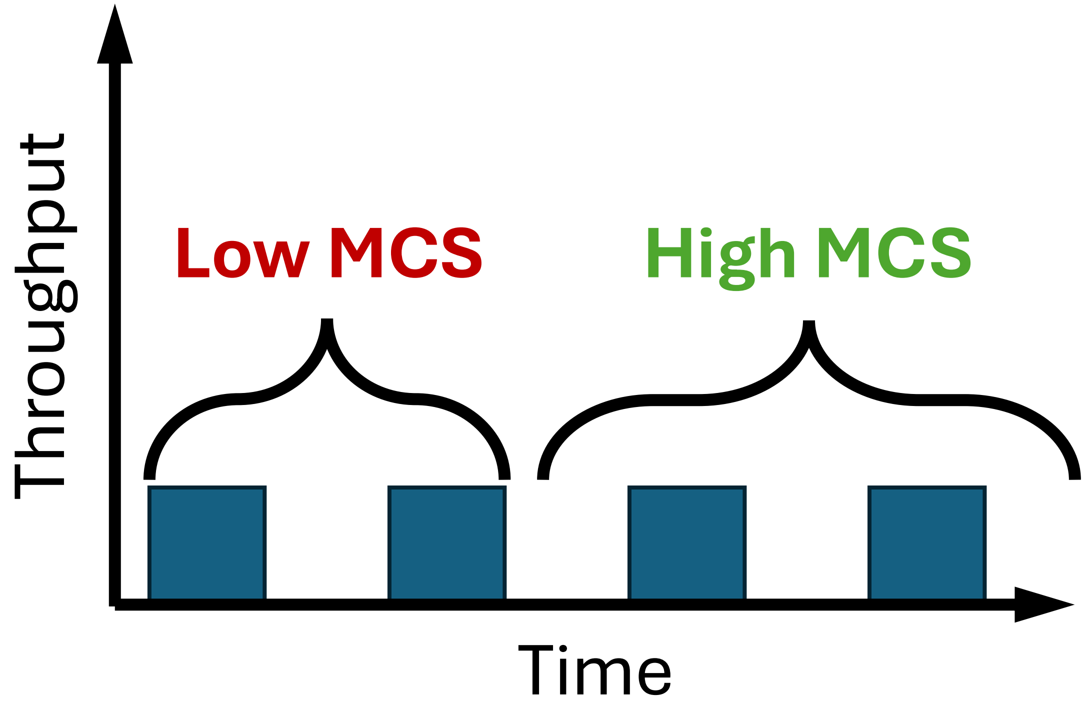
When **less users share the same subframe**, base-station energy decreases

Observation 3: Using Better Network Conditions Saves Energy

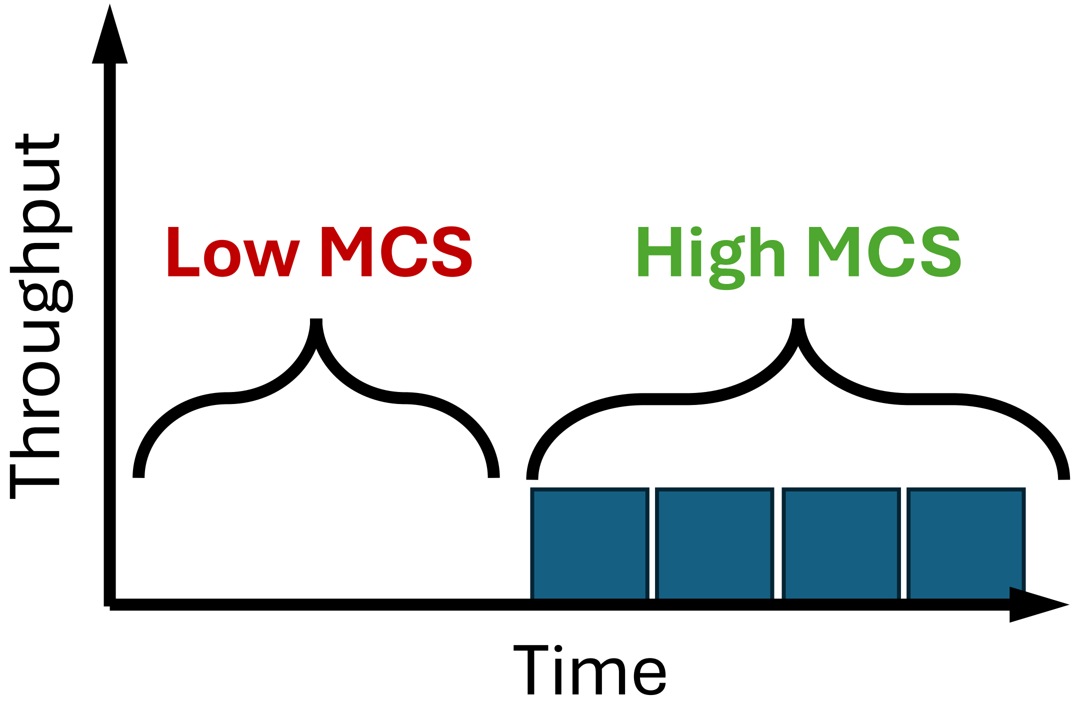


Higher data rates consume less energy per bit

Idea: Defer Transmissions to Better Channel Conditions



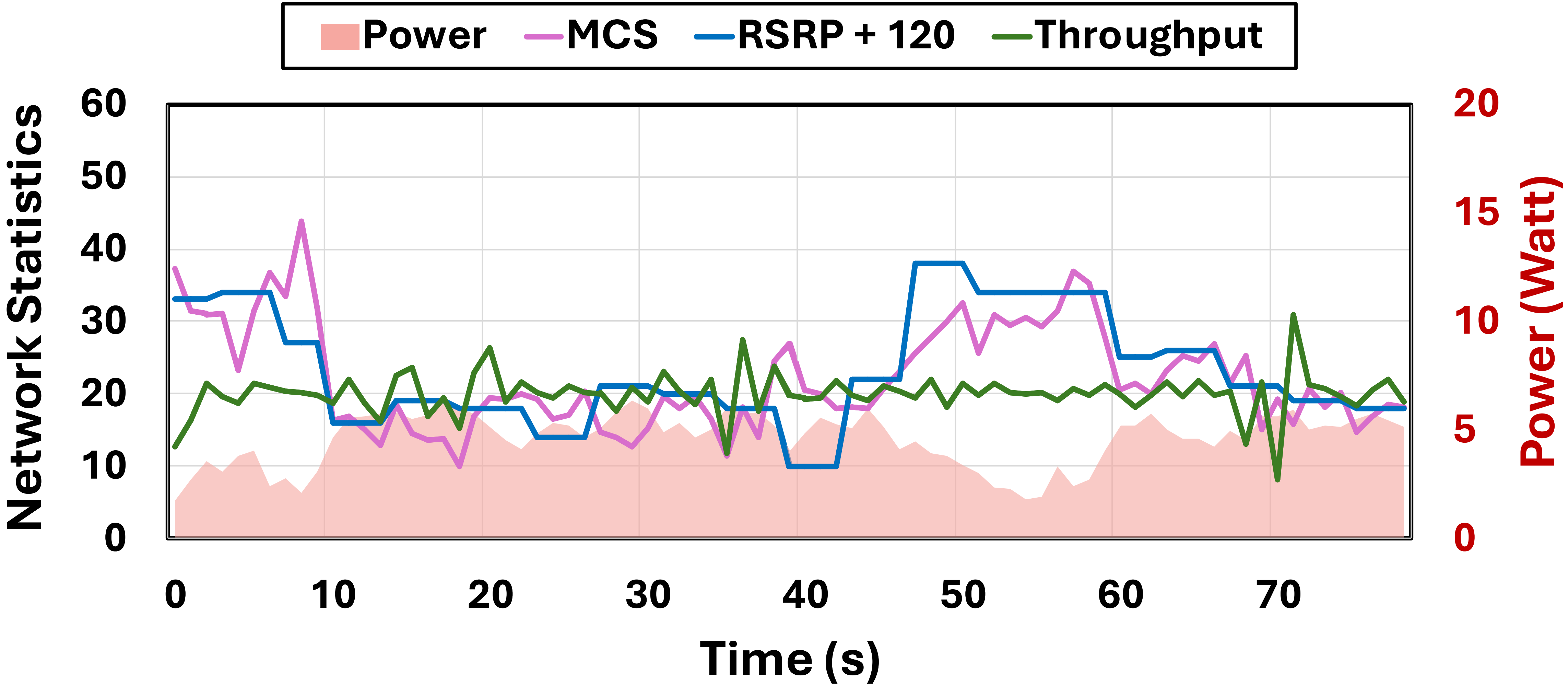
Baseline



Deferring

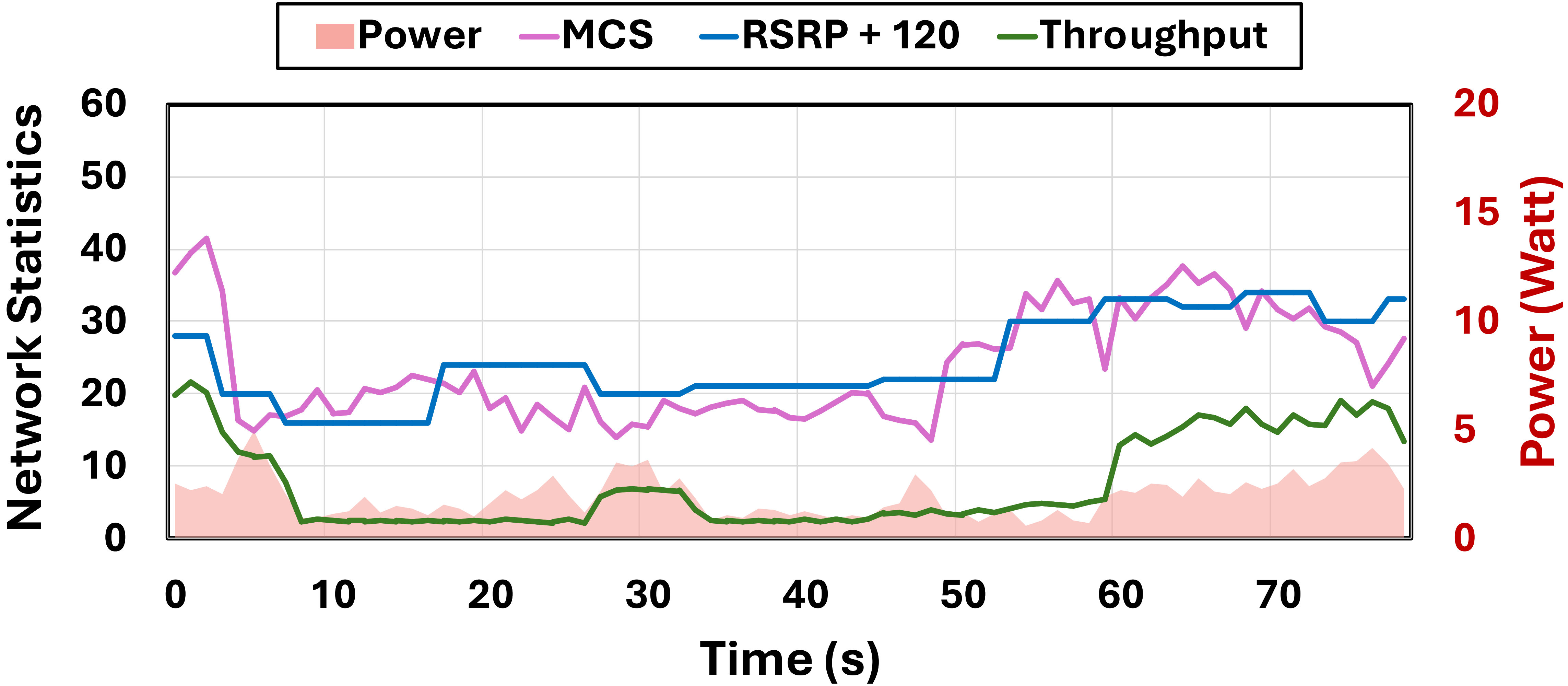
Wait for **good channel conditions** → higher MCS → more bits in one subframe

Microbenchmark: Baseline



Baseline's Dynamic Energy Consumed: 362 J

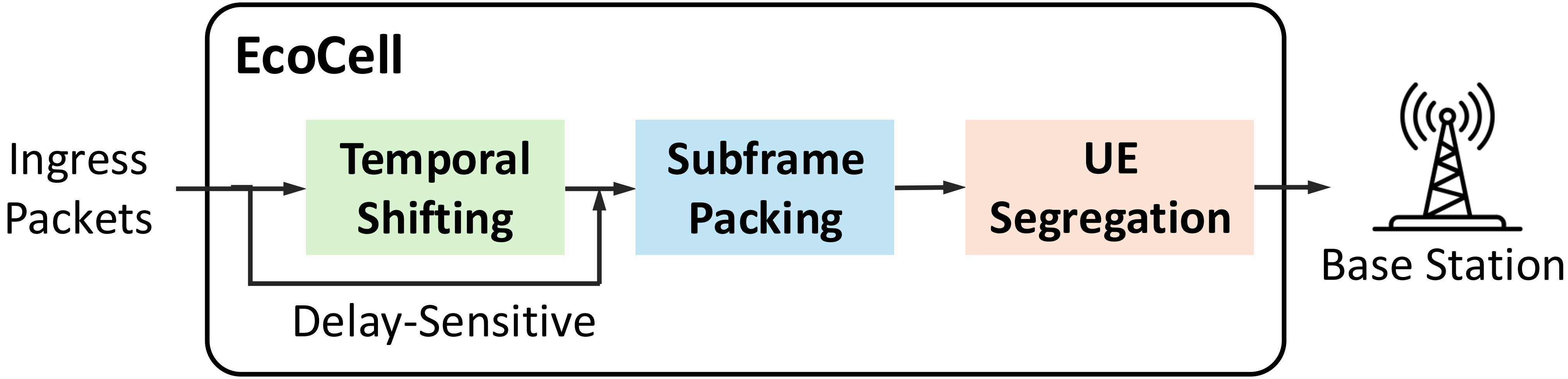
Microbenchmark: Ours



Our Dynamic Energy Consumed: 317 J

Sending at Higher MCS → More Energy Savings

Design of **EcoCell**



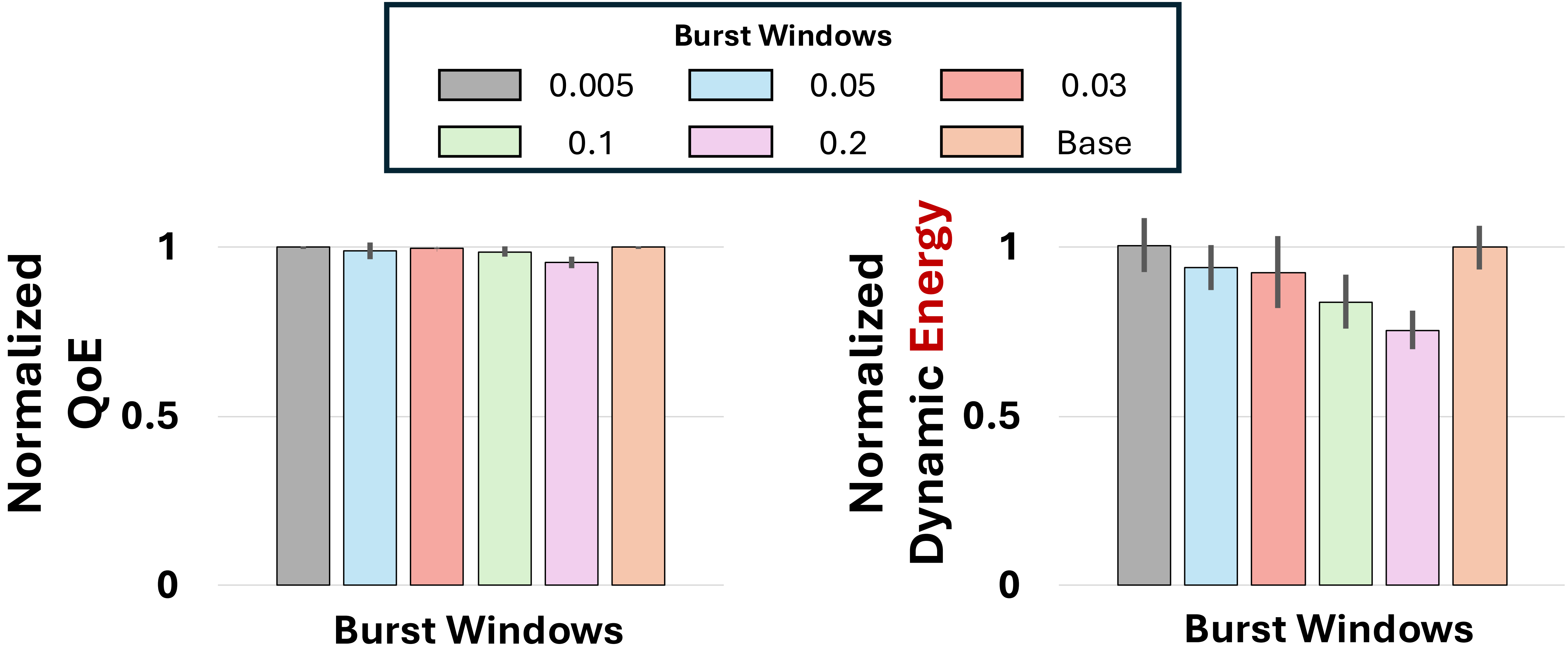
1. **Use higher MCS when possible**

2. **Introduce burstiness to pack data in fewer subframes**

3. **Have fewer UEs per Subframe**

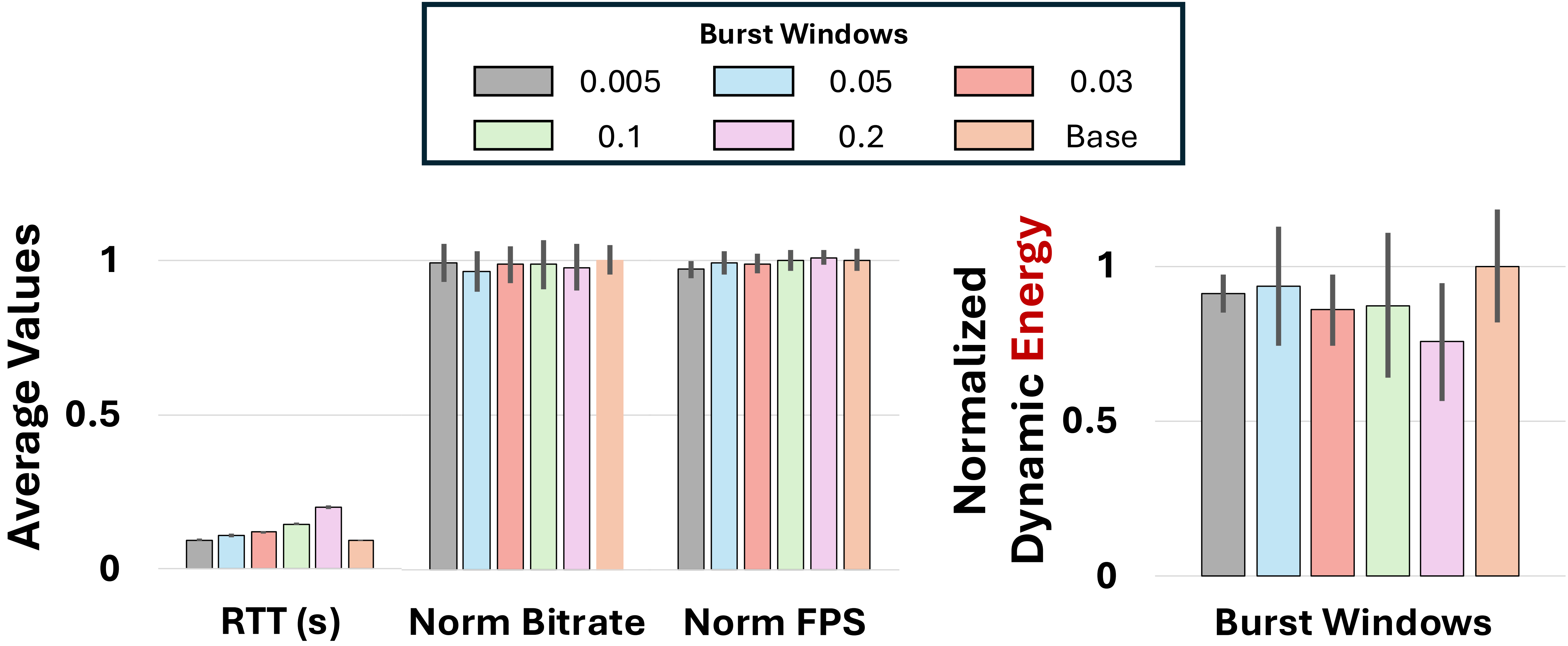
What are the **application-layer tradeoffs** for EcoCell’s design?

Video Streaming



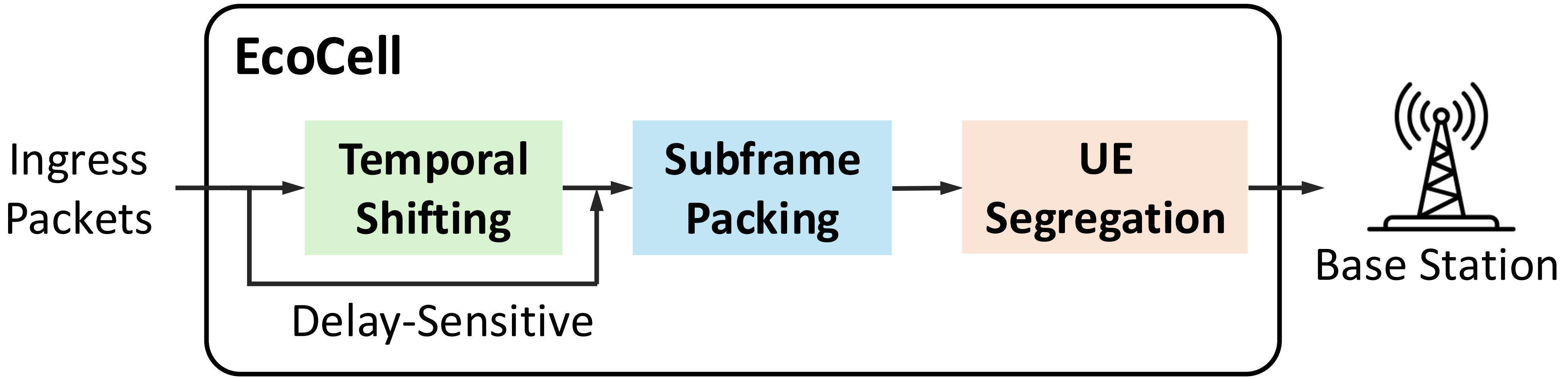
EcoCell can be aggressively bursty and still "look the same" to users
e.g., at 0.2s bursts it saves **~40% energy** with only **~4.5% QoE drop**

Video Conferencing



EcoCell can tune the **energy-QoE tradeoff** depending on the application

Conclusion



- **EcoCell saves base-station energy by shaping traffic patterns**
- **It's practical and deployable today:** software-only middlebox with simple knobs (e.g., burst period) to tune the energy–QoE tradeoff