Energy-Efficient Orchestration of Metro-Scale 5G Radio Access Networks

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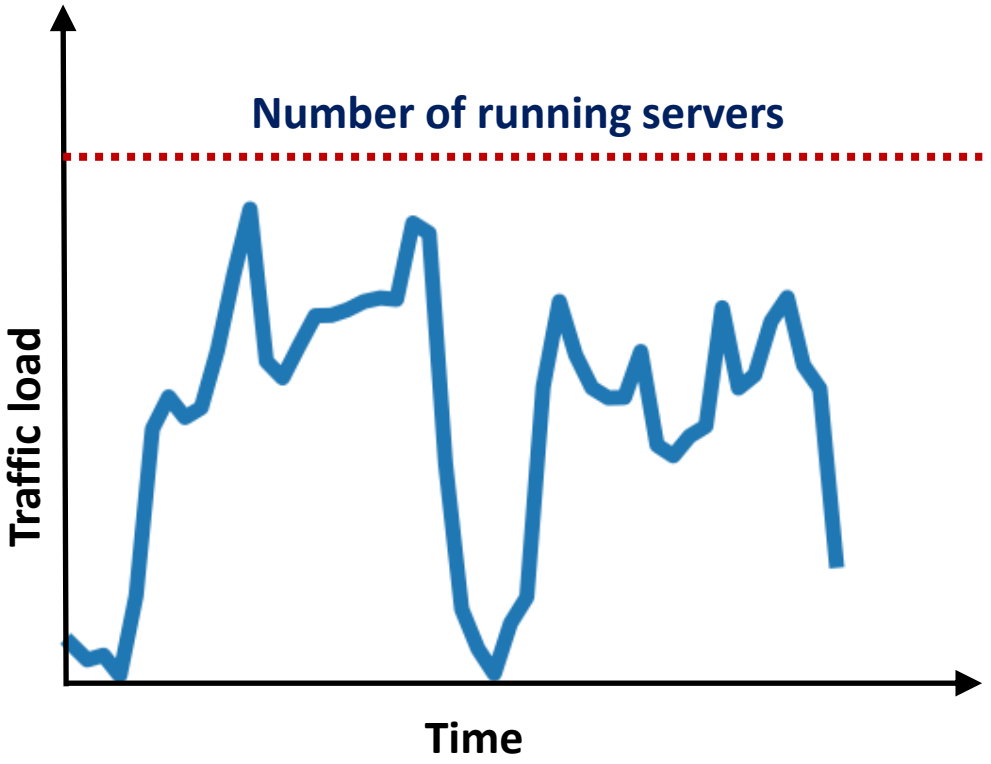
RAN Energy Consumption Problem

Overprovisioning

1. Traffic load varies with time
2. Server capacity is greater than demand



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1. Traffic load varies with time
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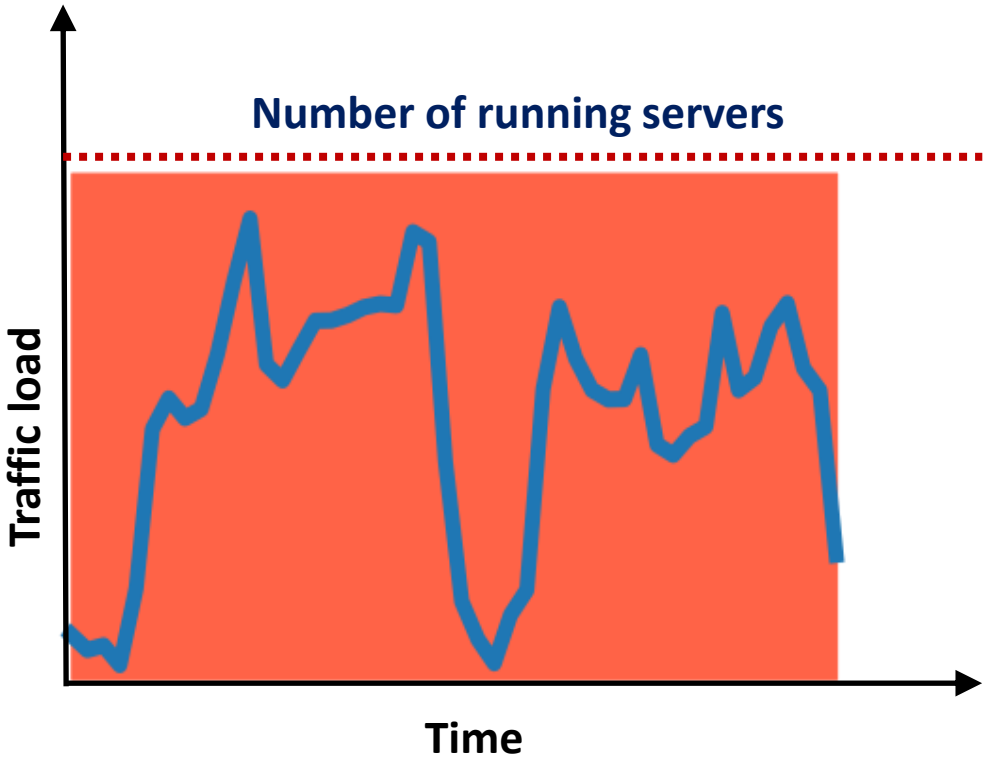
3. At lower traffic, static energy incurs huge costs
4. Leads to inefficient resource utilization



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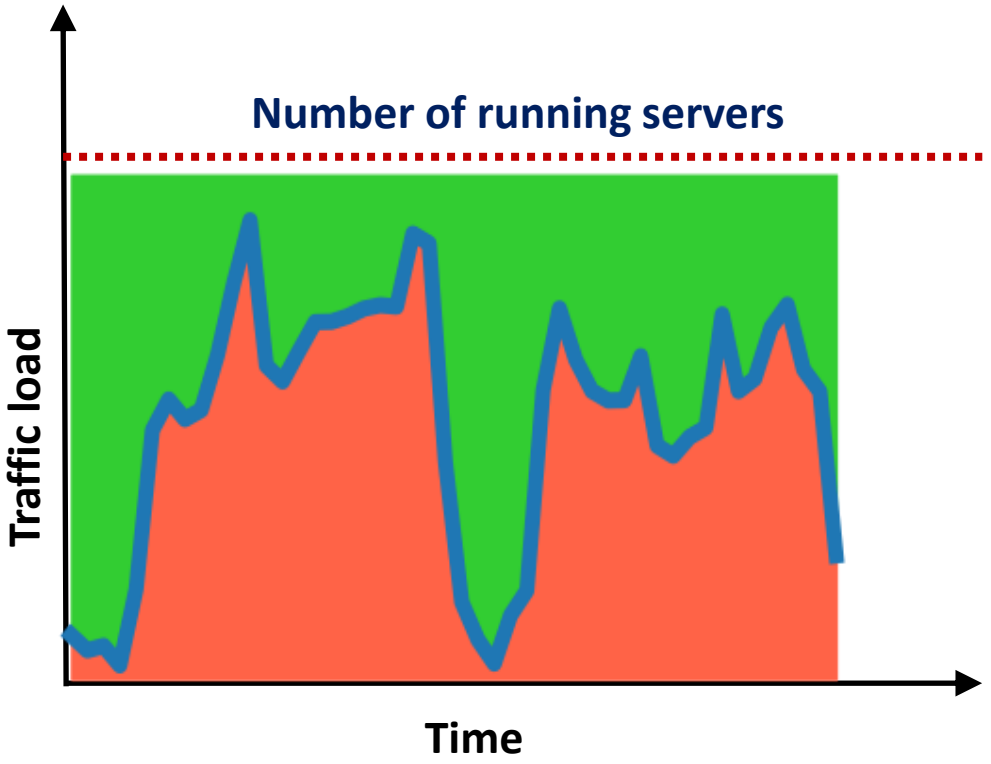

Need advanced measures to perform optimal resource orchestration

Our Contributions

- Realistic multi-tier cloudified RAN model
- Comprehensive energy model and problem formulation
- A distributed and scalable solution: GreenRAN
- Evaluation with metro-scale real world dataset

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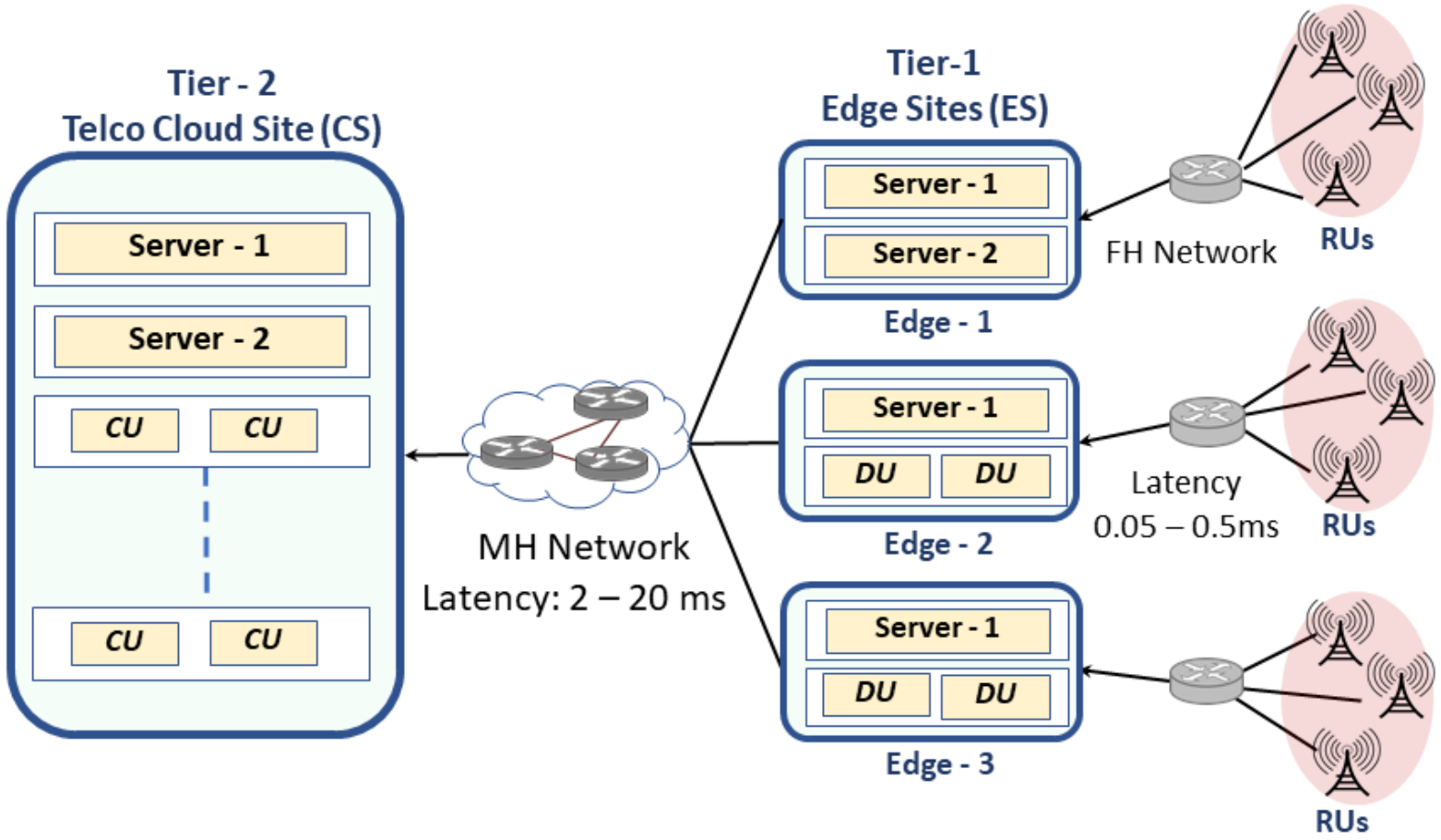
Multi-tier vRAN Architecture



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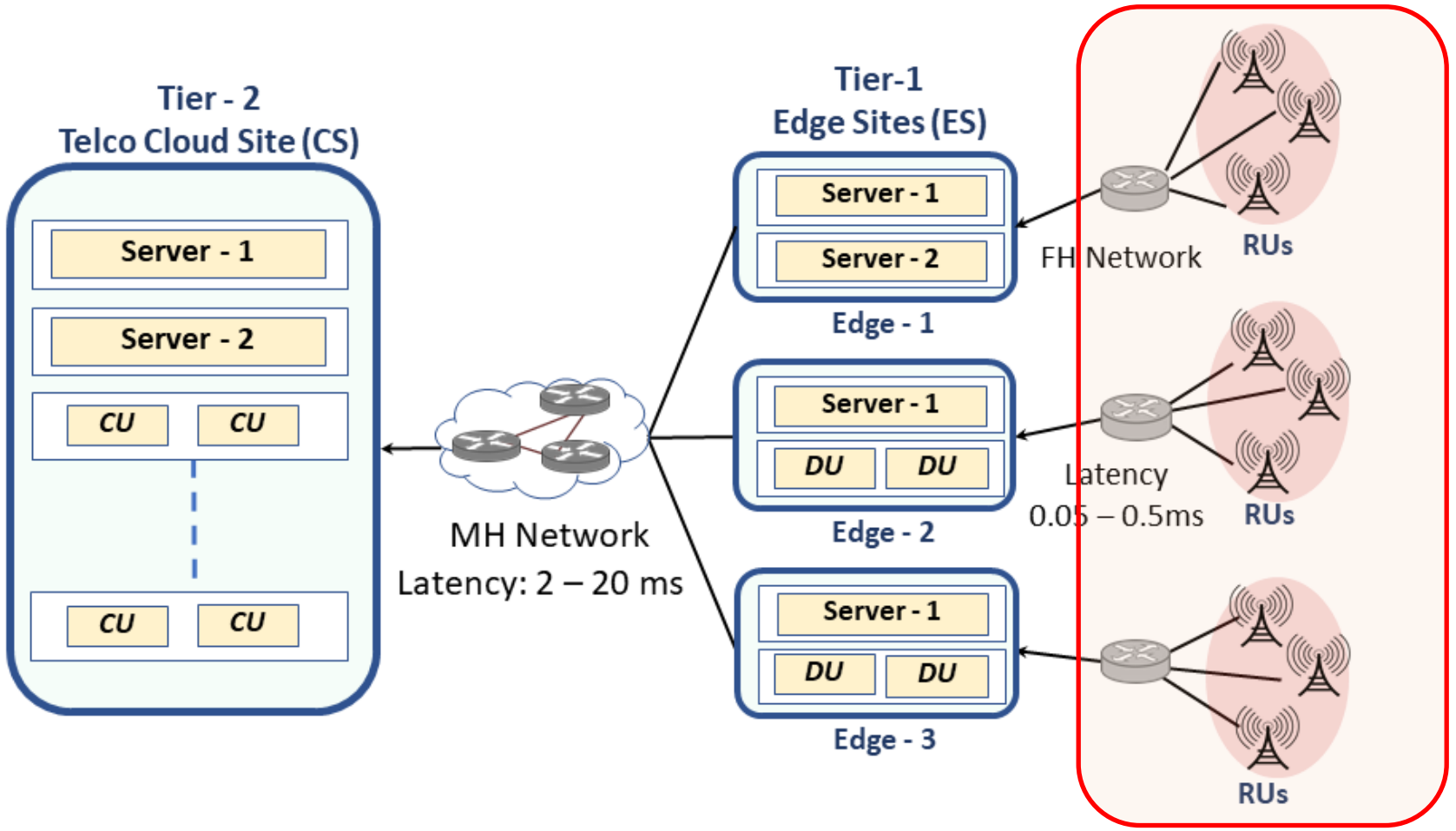

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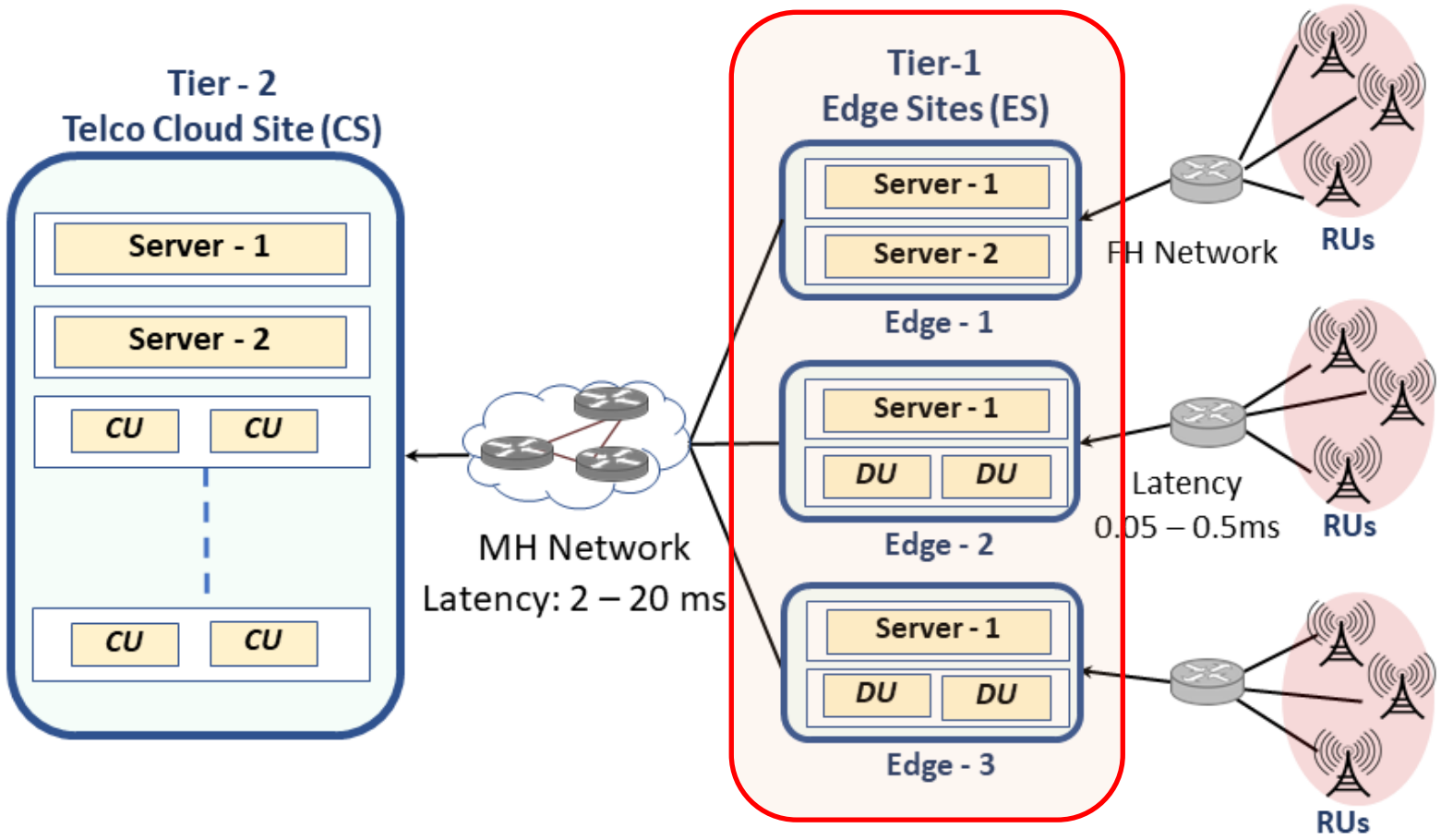
- VNF consolidation



Multi-tier vRAN Architecture

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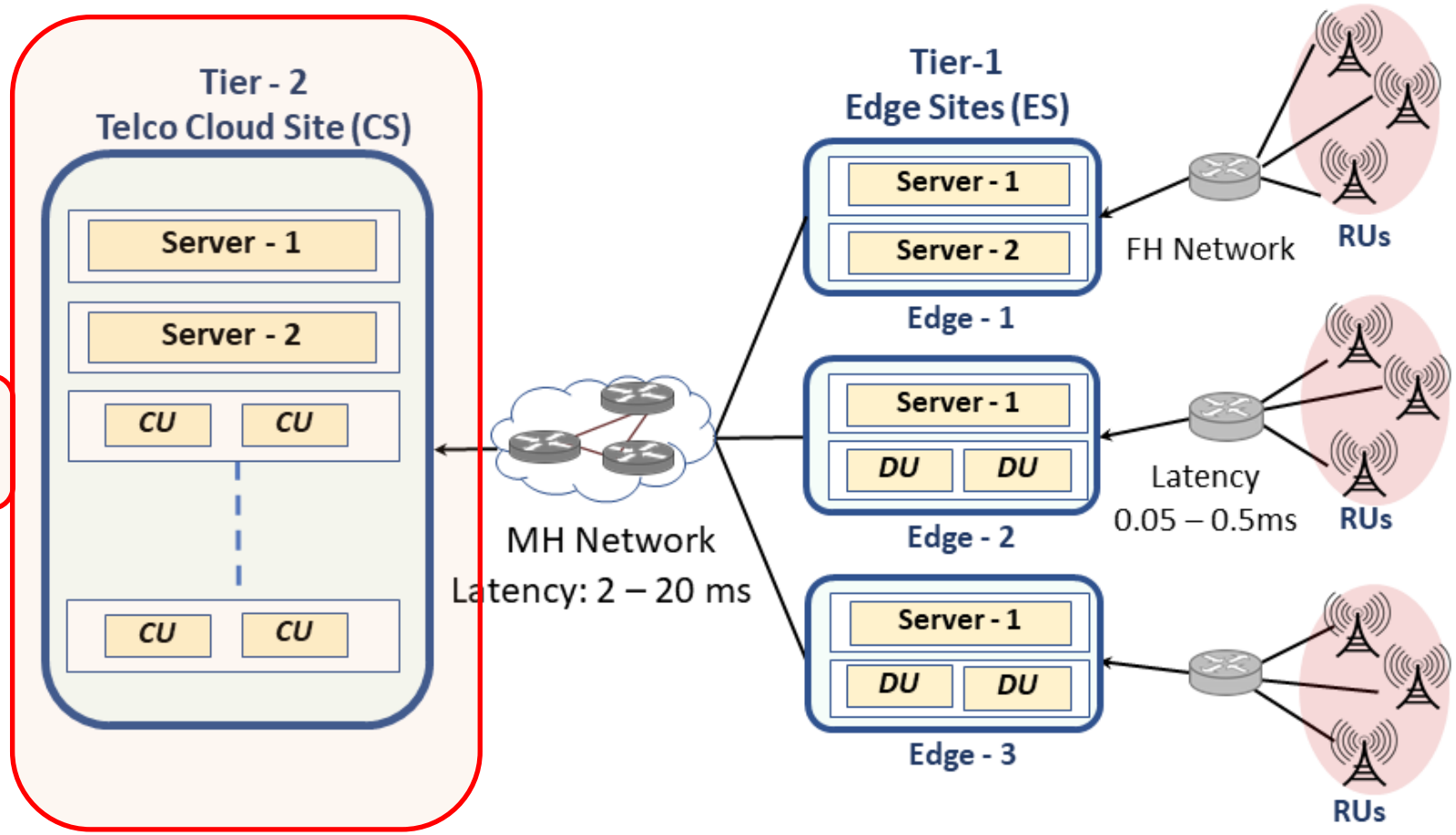
- More energy efficient



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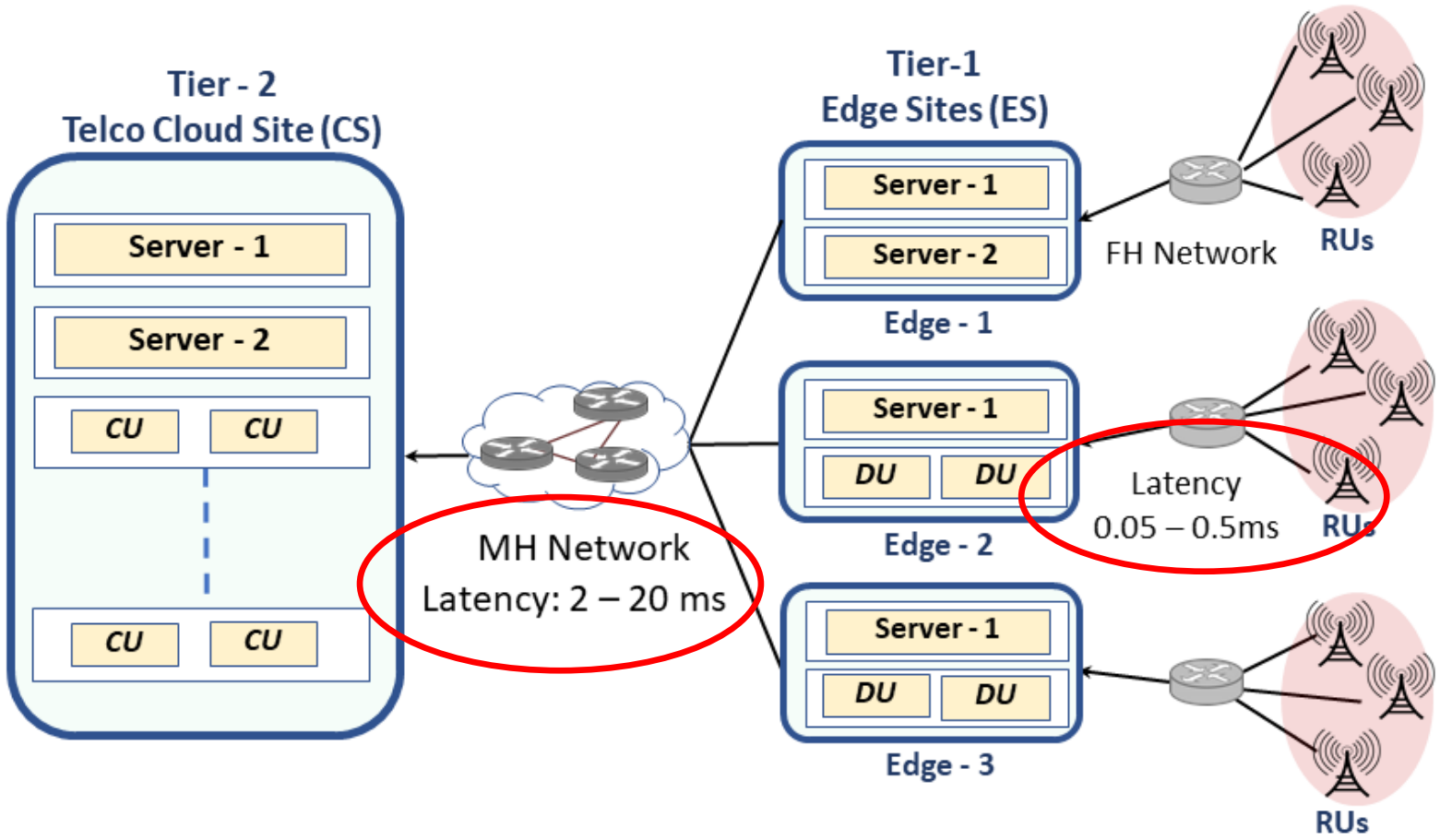
- More energy efficient
- However, latency issues
- MH link capacity issues



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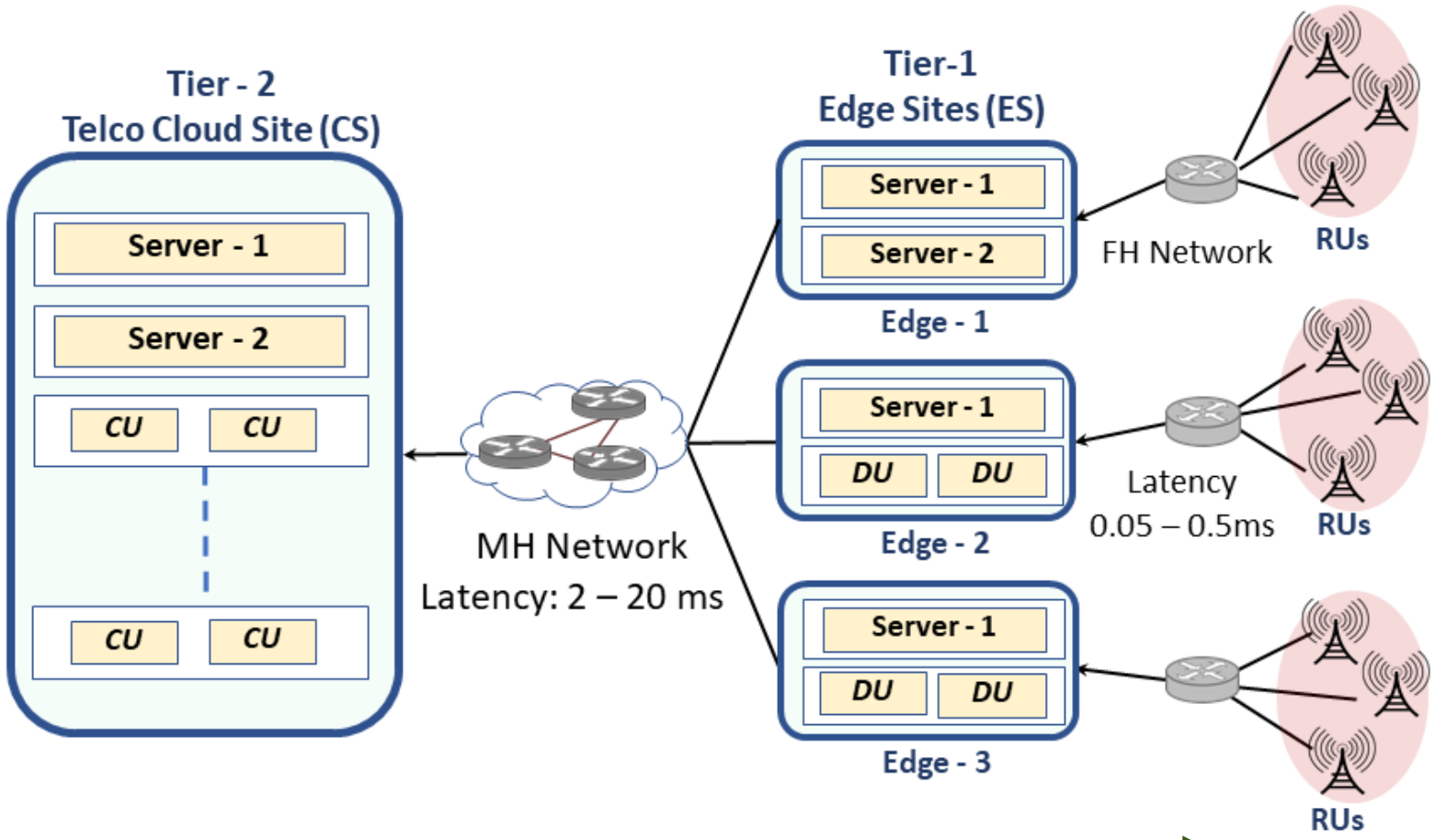
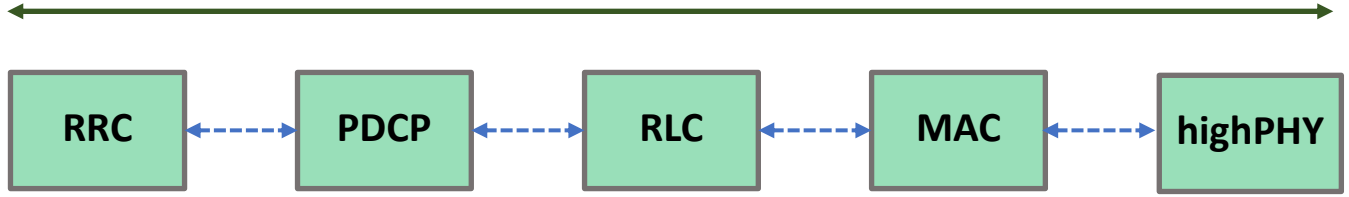


RAN Functional Splits



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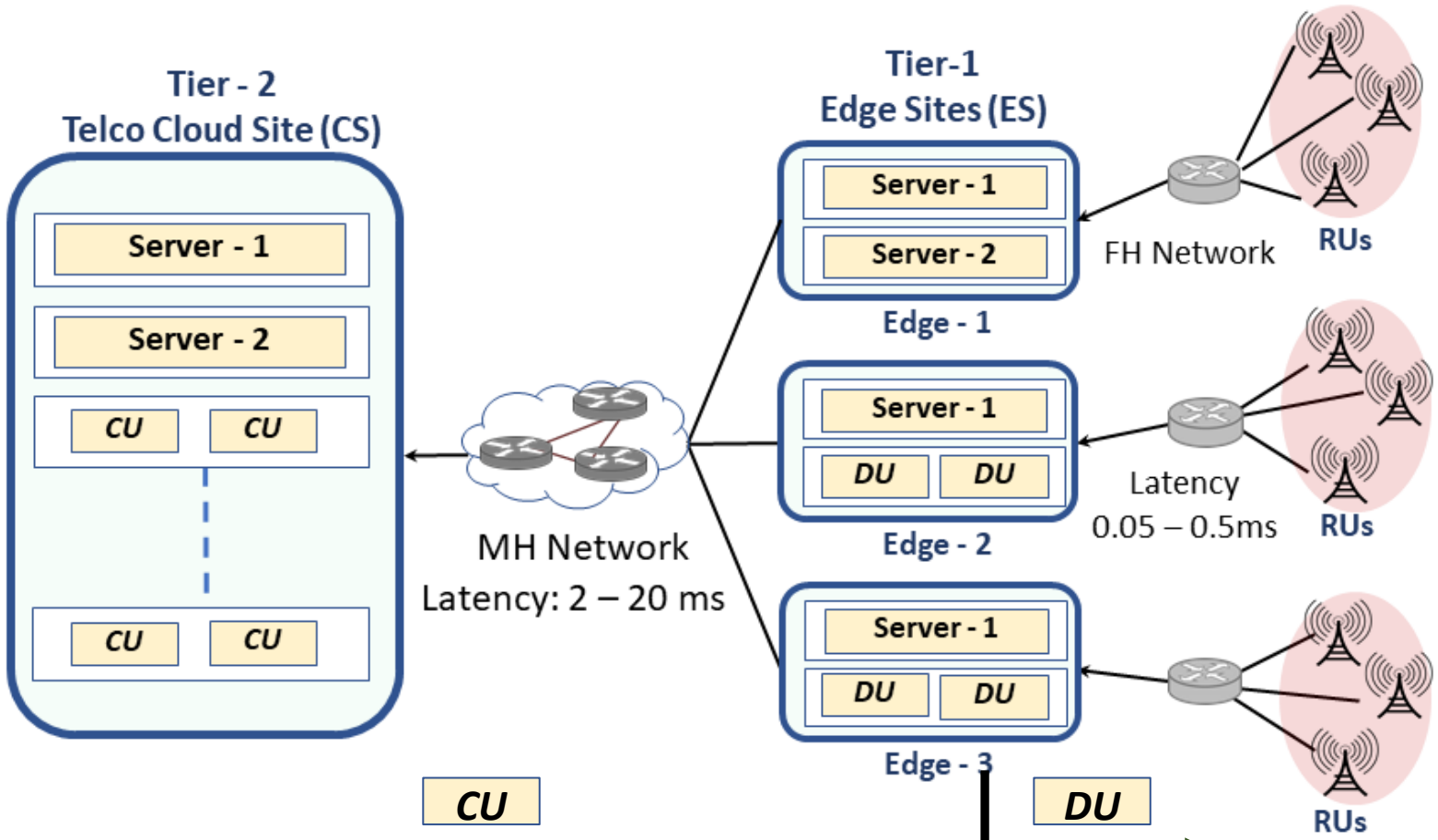

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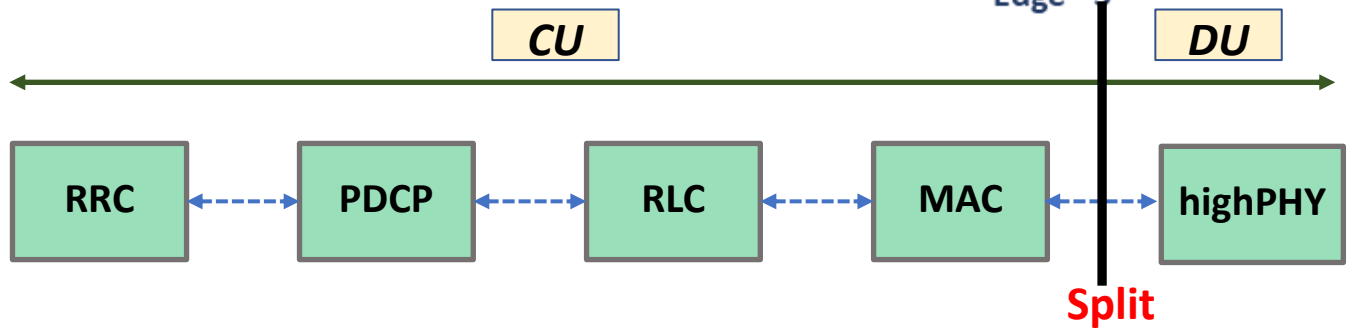

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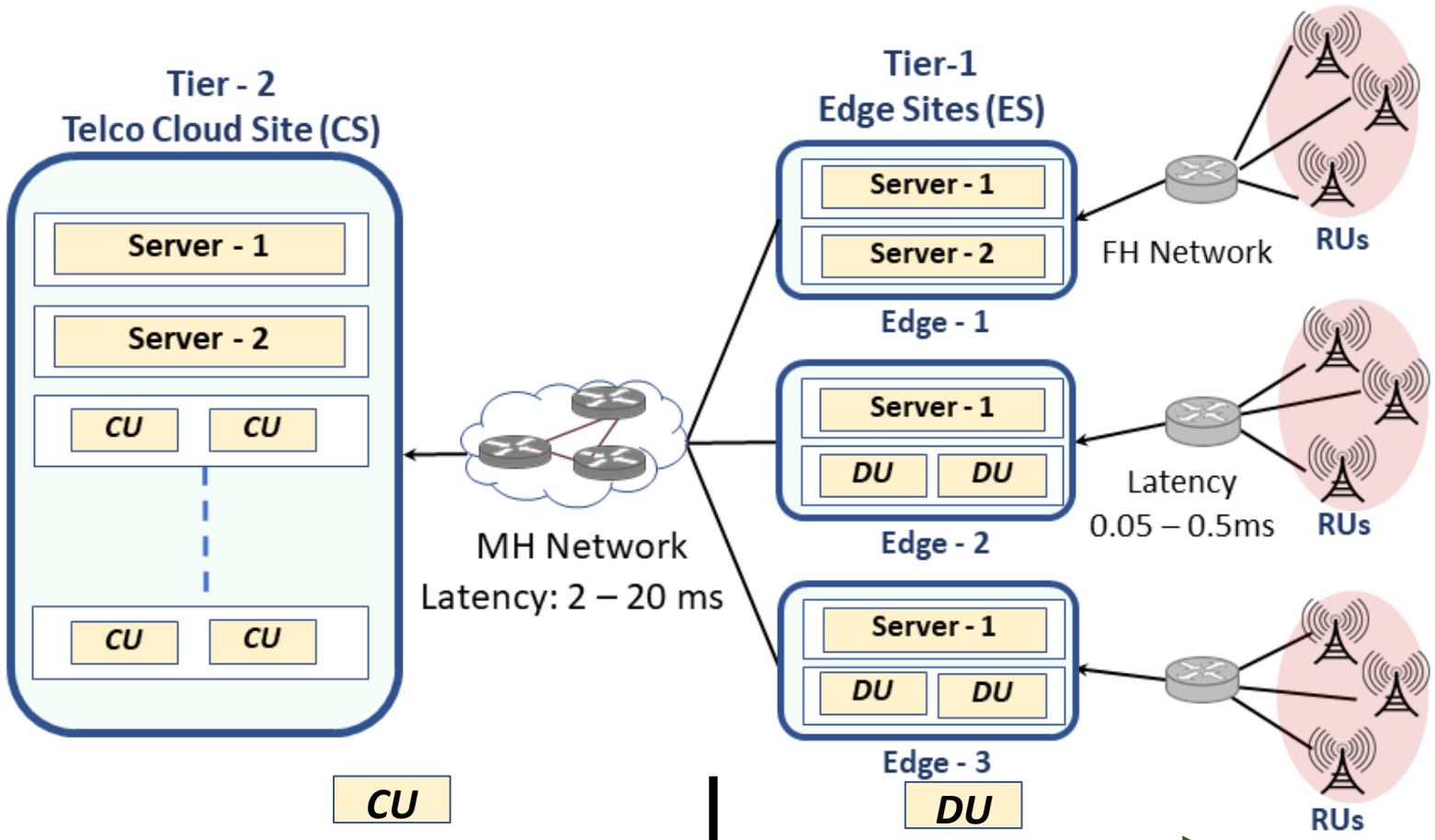

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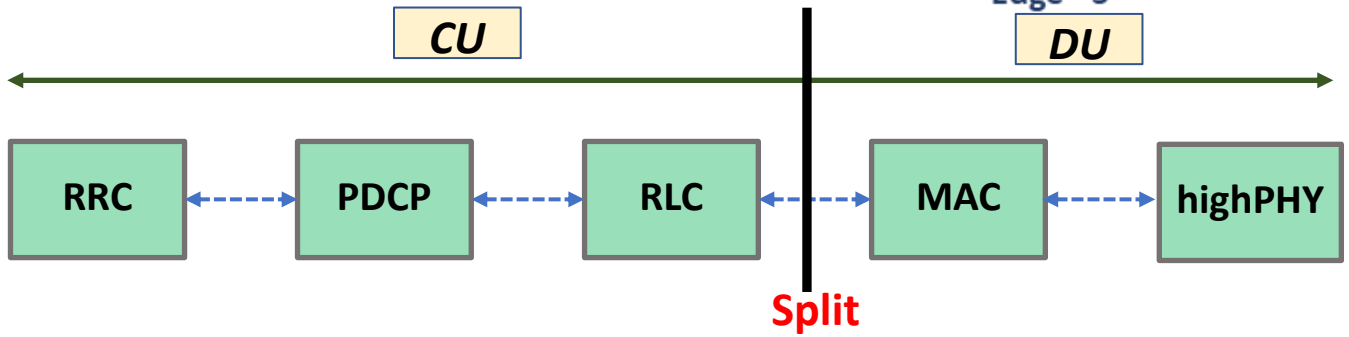

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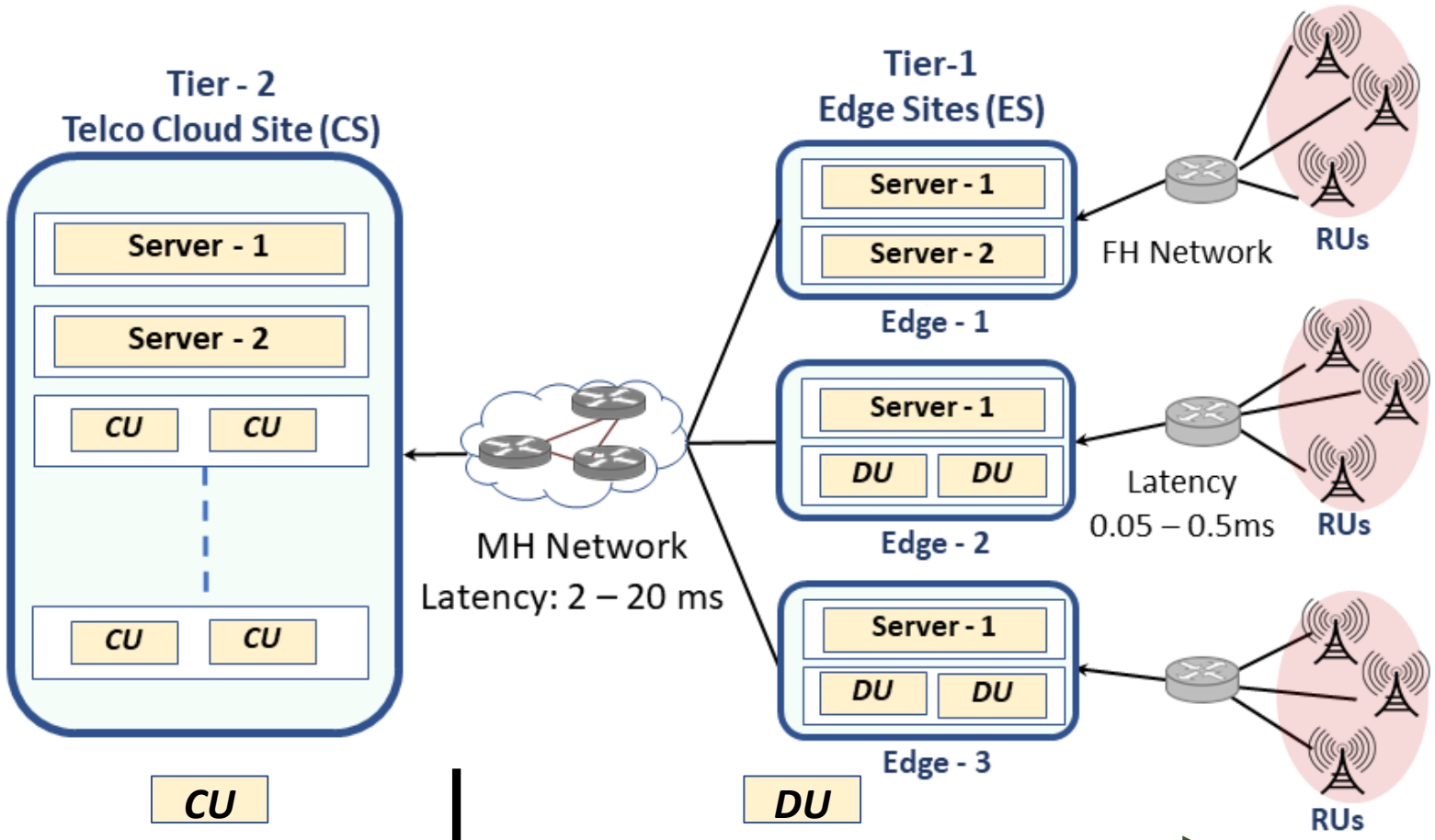

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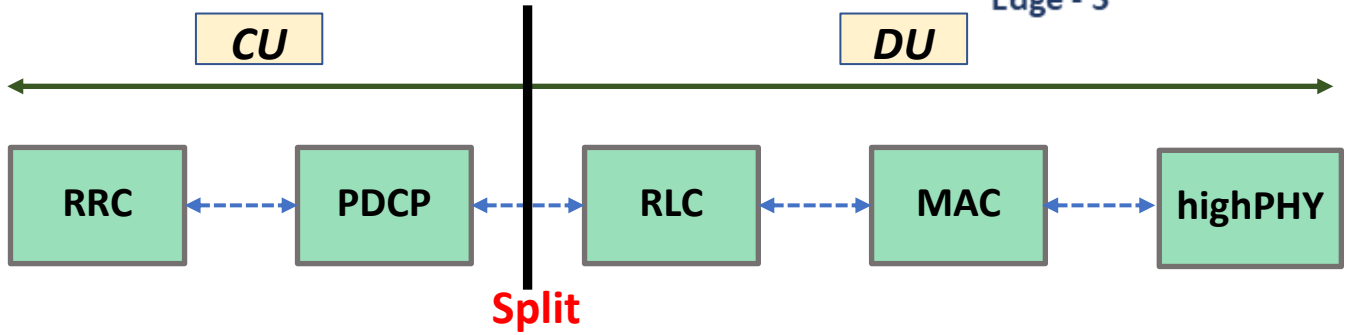

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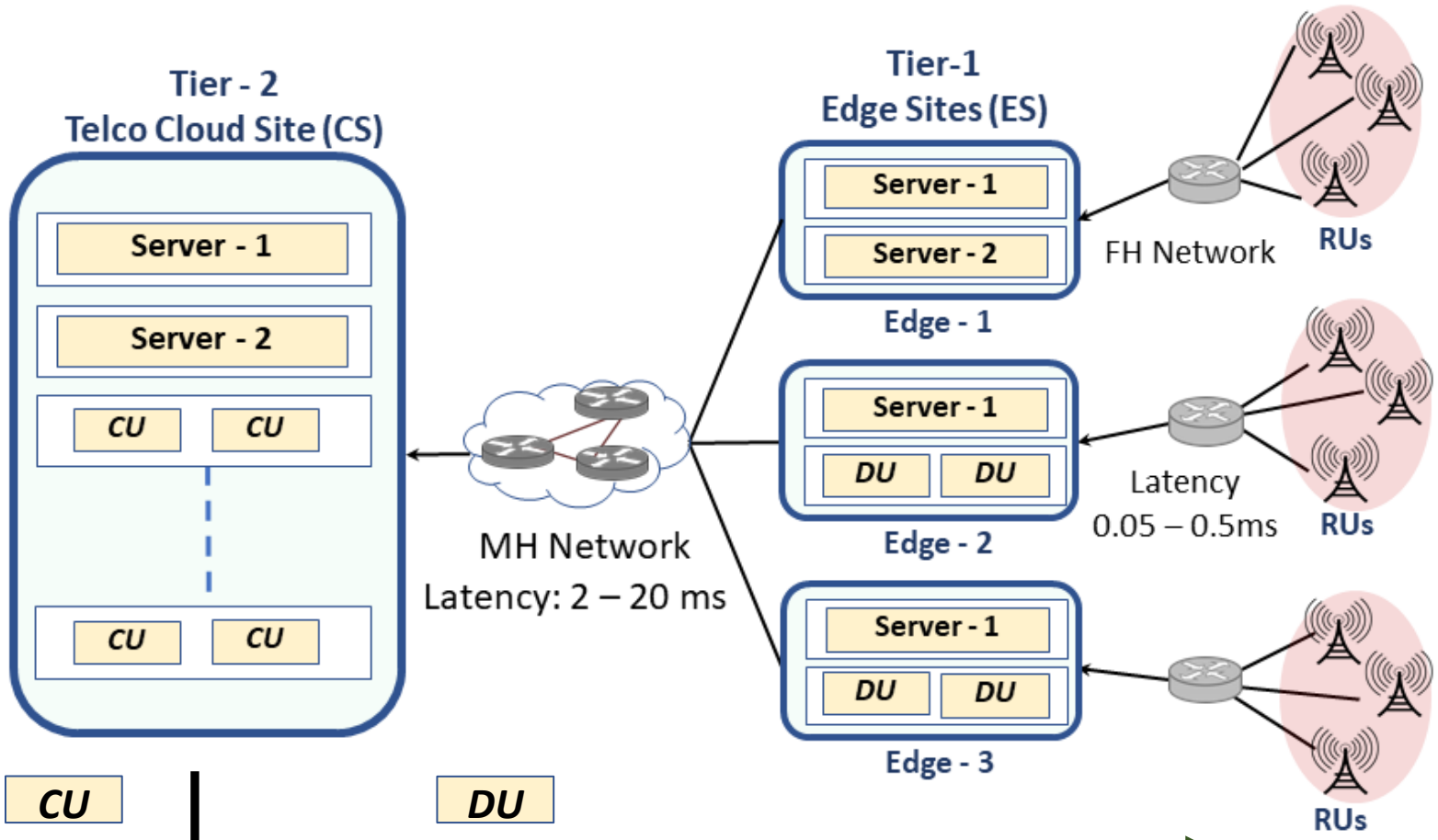

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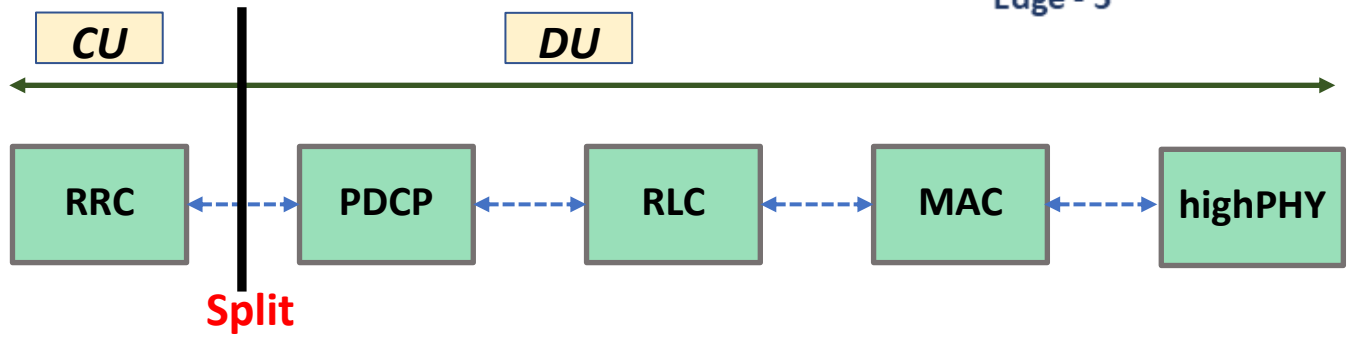

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Energy Model

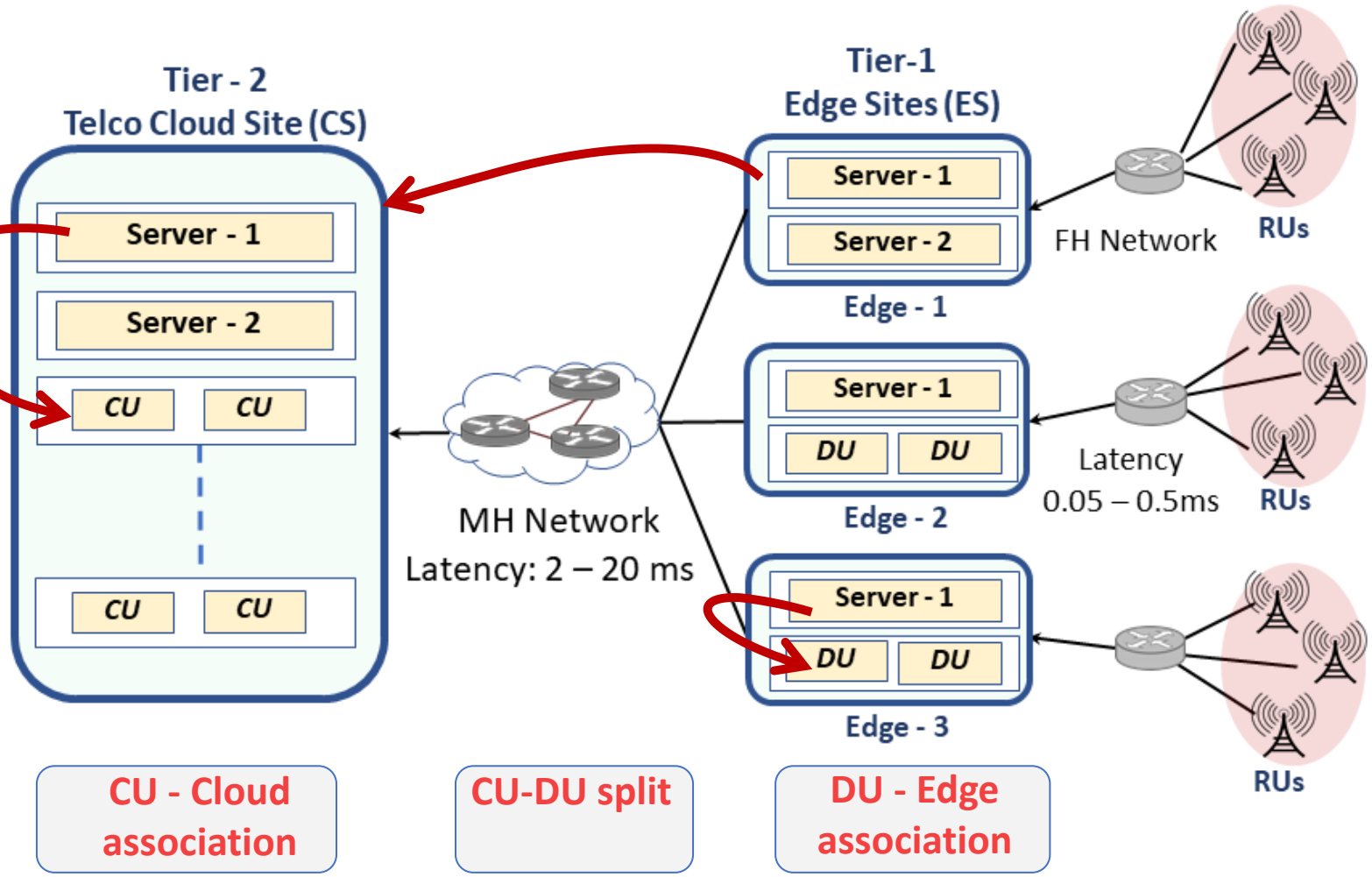
Processing cost (E^P)

- To process VNFs
- Coupled bin-packing

Migration cost (E^M)

- To consolidate VNFs
- Consider previous epoch

Decision variables



Challenges

NP hard

- Integer Quadratic Program

Scale

- Huge parameter space

Centralized

- Edge and Cloud variables are inter-dependent

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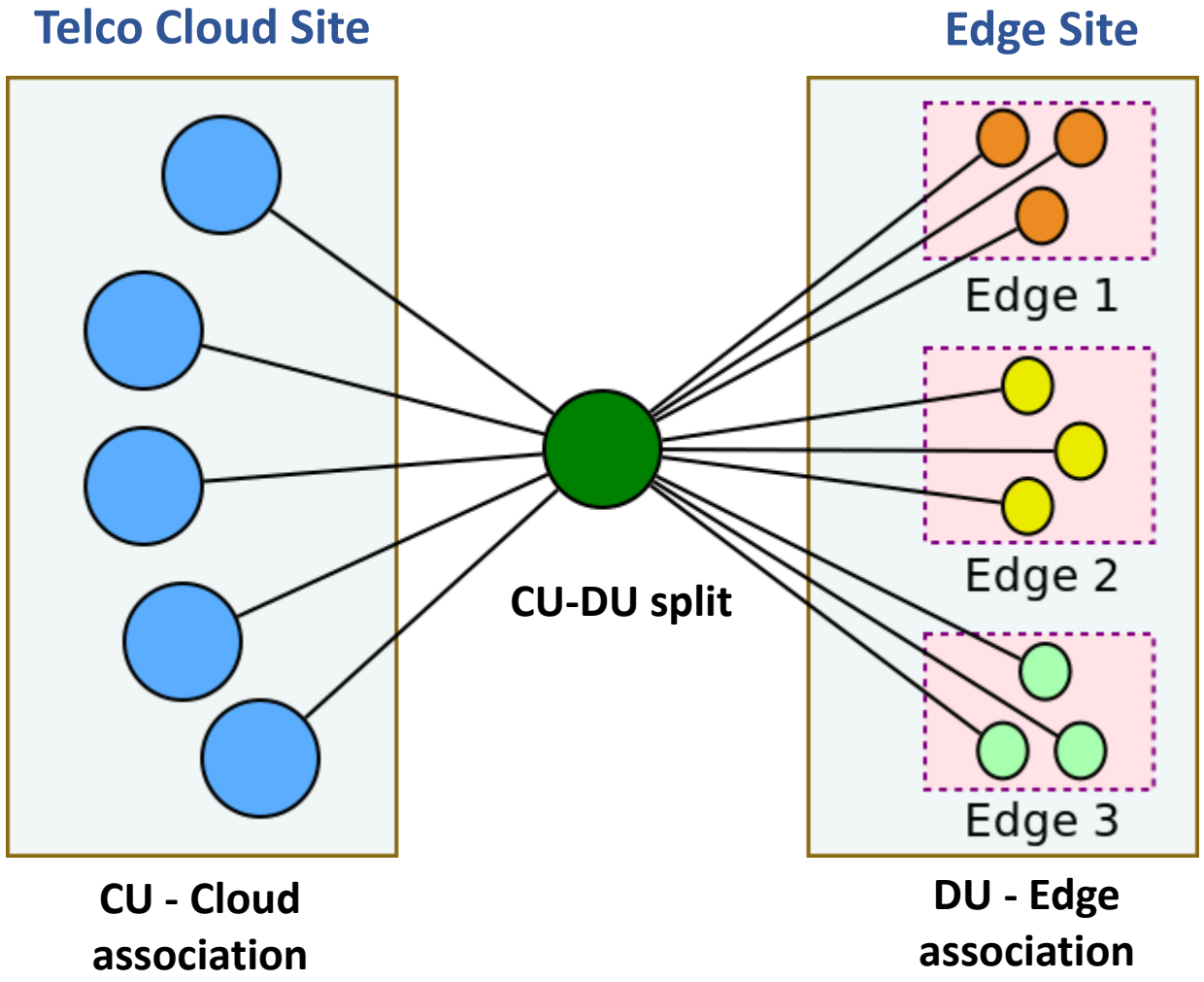
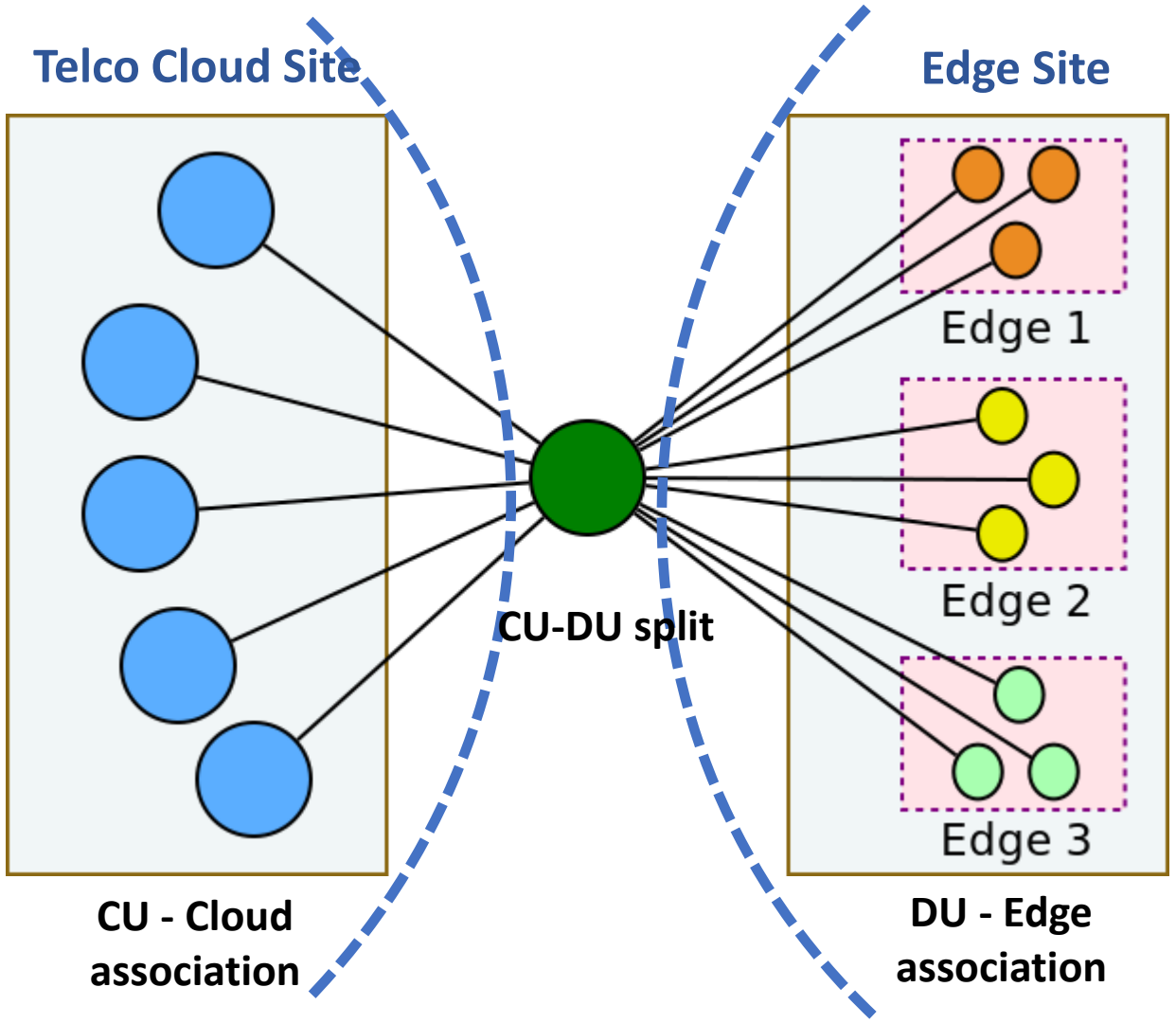
Towards a decentralized solution: GreenRAN



Towards a decentralized solution: GreenRAN

Divide & Conquer Paradigm

1. Lagrangean Relaxation



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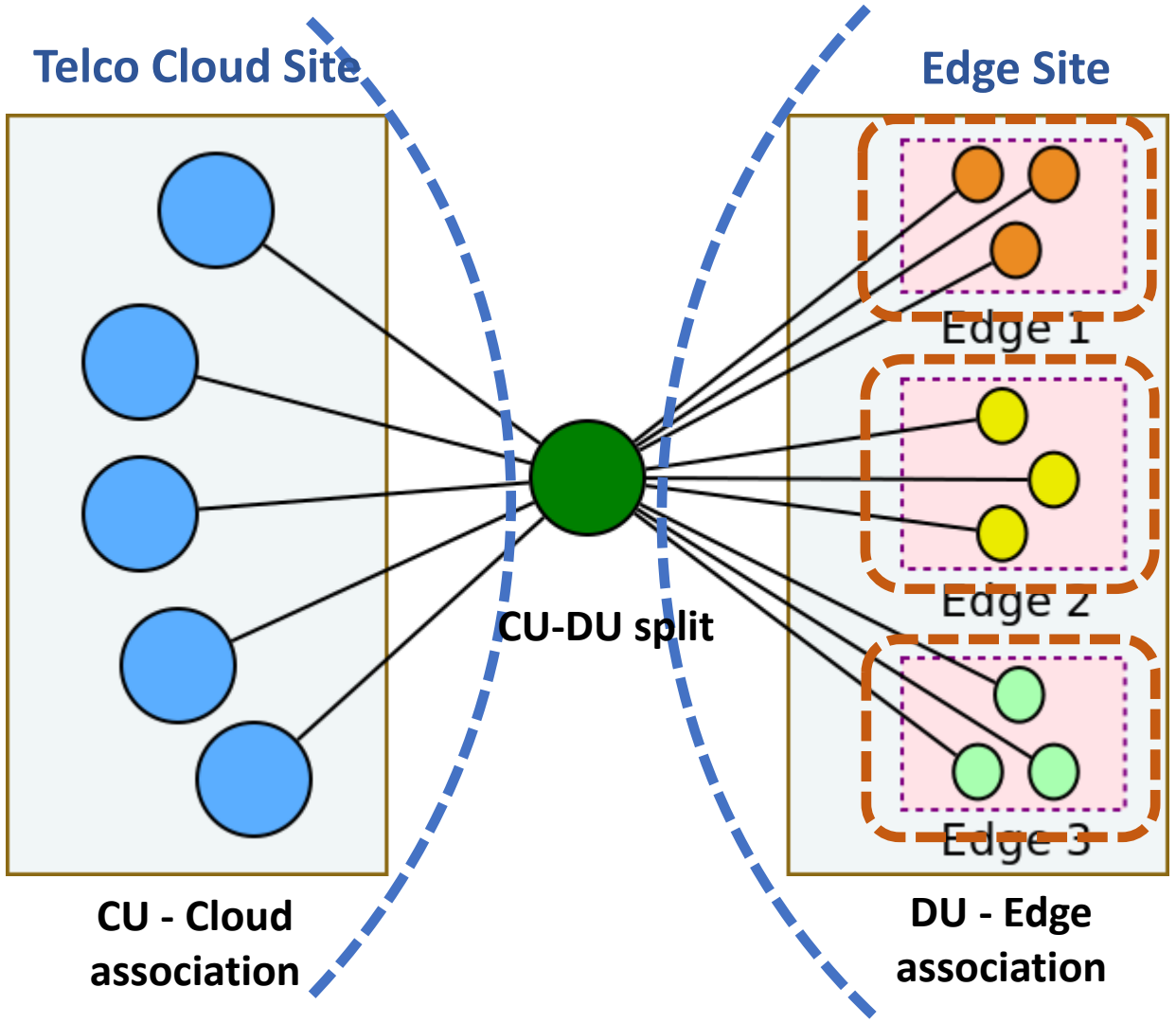
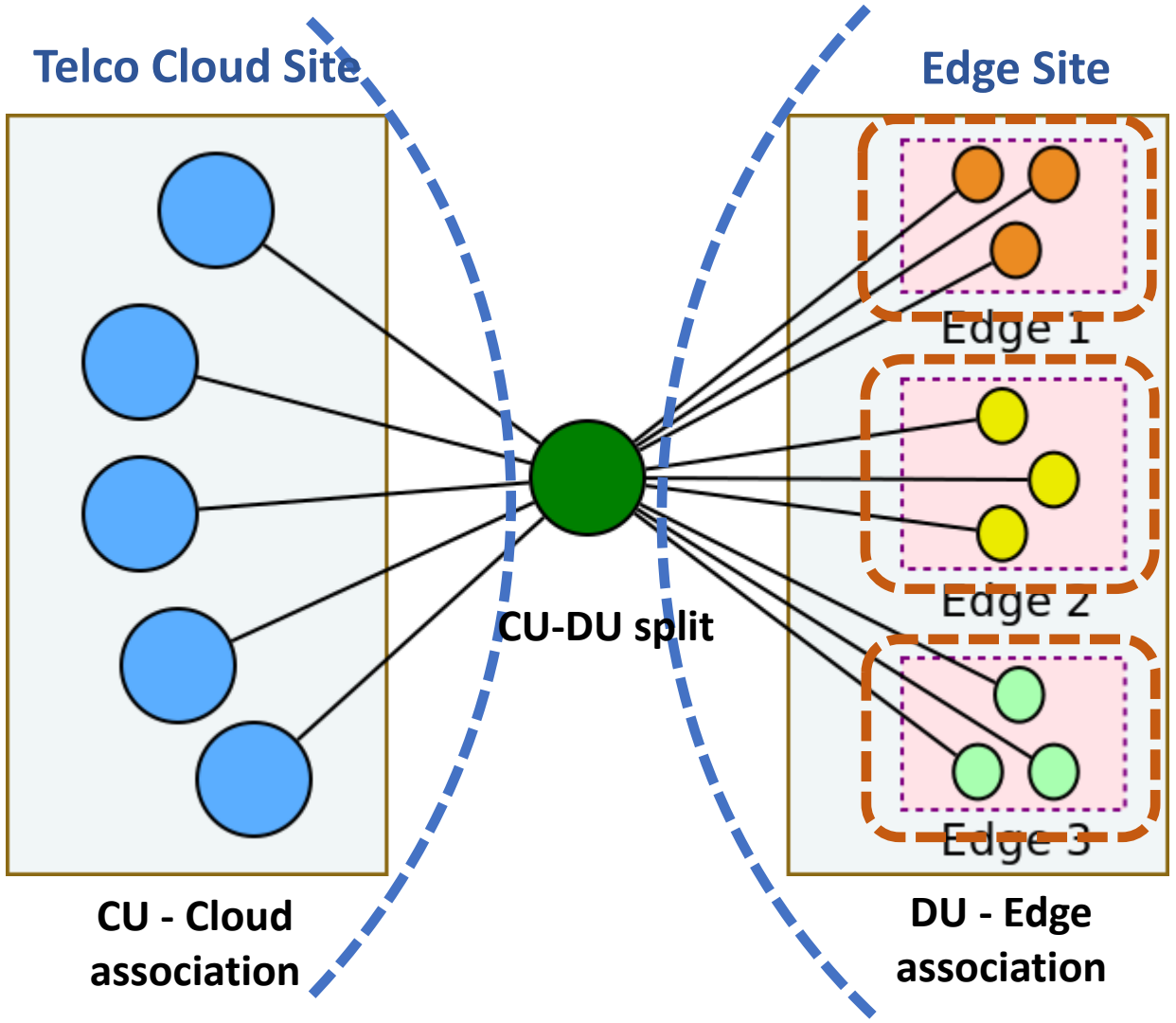


Towards a decentralized solution: GreenRAN

Divide & Conquer Paradigm

1. Lagrangean Relaxation
2. Per edge formulation
3. Simulated Annealing



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Experimental Setup

vRAN Configuration

- Metro-scale **real world traffic** dataset
- **450** RUs
- **18** Far Edge Clouds
  - **15** physical servers per Edge Cloud
- **1** Telco Cloud
  - **30** servers per Telco Cloud

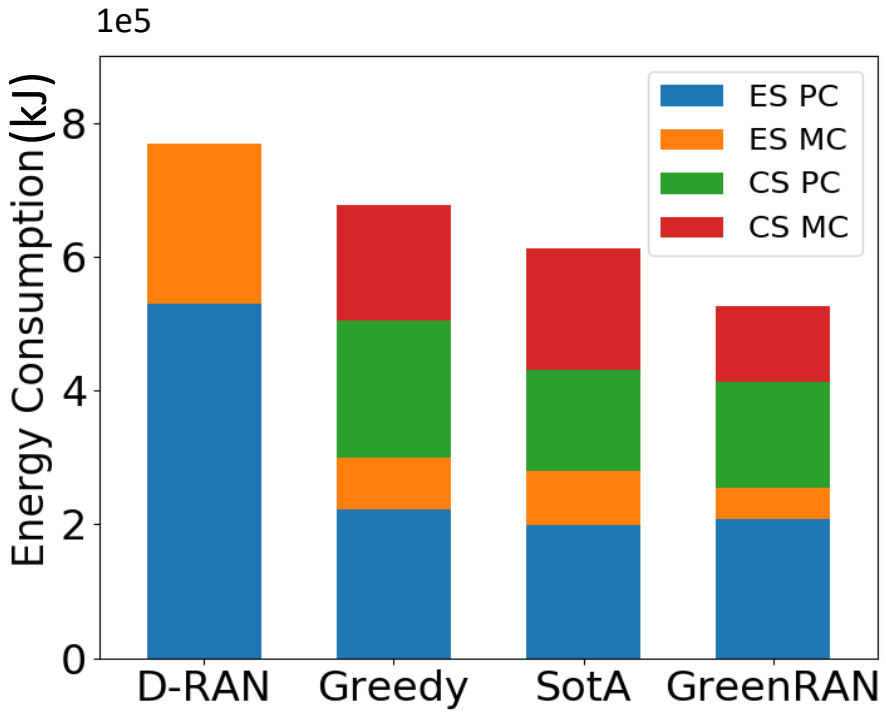
Benchmarks

- **D-RAN**
  - All processing in DUs at Far edge site
- **Greedy**
  - Maximum processing at CU in Telco cloud
- **SotA**
  - Only considers the processing cost

SotA: H. Gupta et al., “Apt-RAN: A Flexible Split-Based 5G RAN to Minimize Energy Consumption and Handovers,” TNSM, 2020

Energy Consumption

- GreenRAN
  - 25% better than SotA
  - 42% better than traditional D-RAN
- D-RAN has fewer multiplexing opportunities
- Greedy offloading to cloud is not optimal
- SotA incurs lesser processing cost
  - But higher migration cost



Conclusion

- Optimizing energy consumption is more challenging with advanced architecture
- We presented a latest vRAN model, realistic energy model considering migration costs
- Our framework, GreenRAN, is a distributed, scalable and highly efficient solution
- Results show 25% improvement over SotA and 42% over D-RAN

Thank You