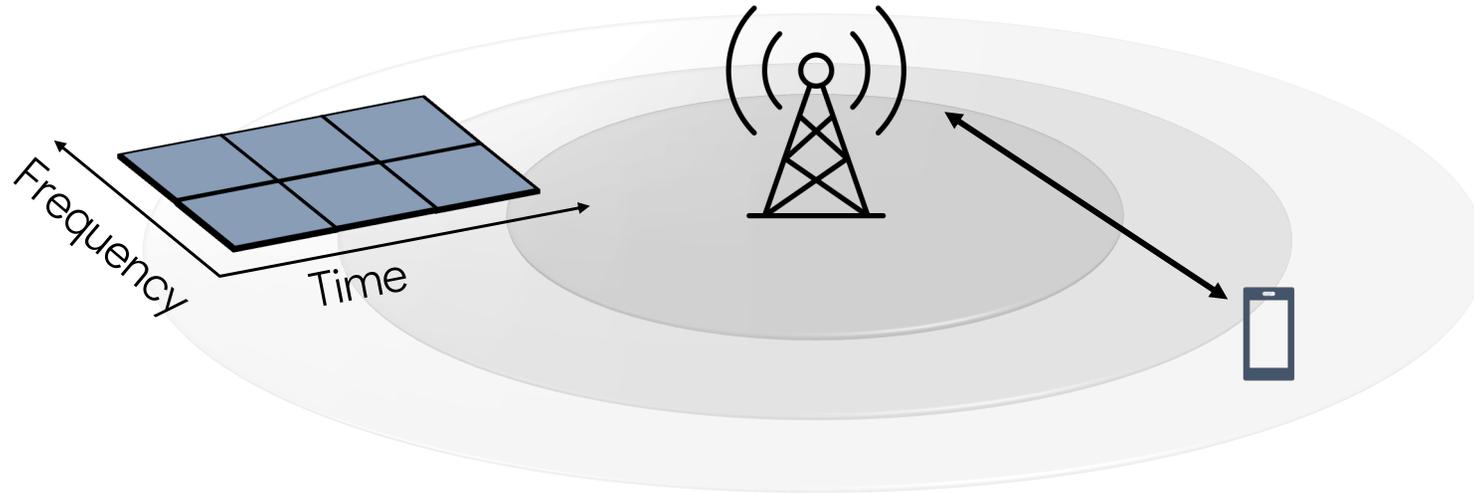


Performance Isolation for 5G RAN Slices Across Multiple Interfering Cells

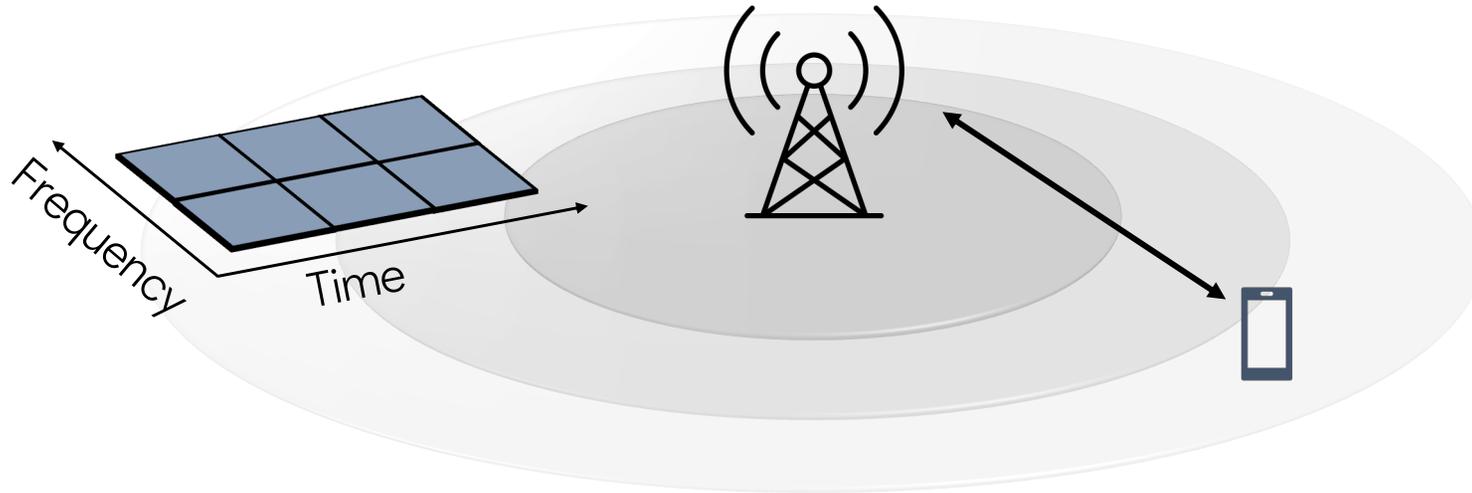
Taimoor Tariq, Yongzhou Chen, Haitham Hassanieh, Radhika Mittal



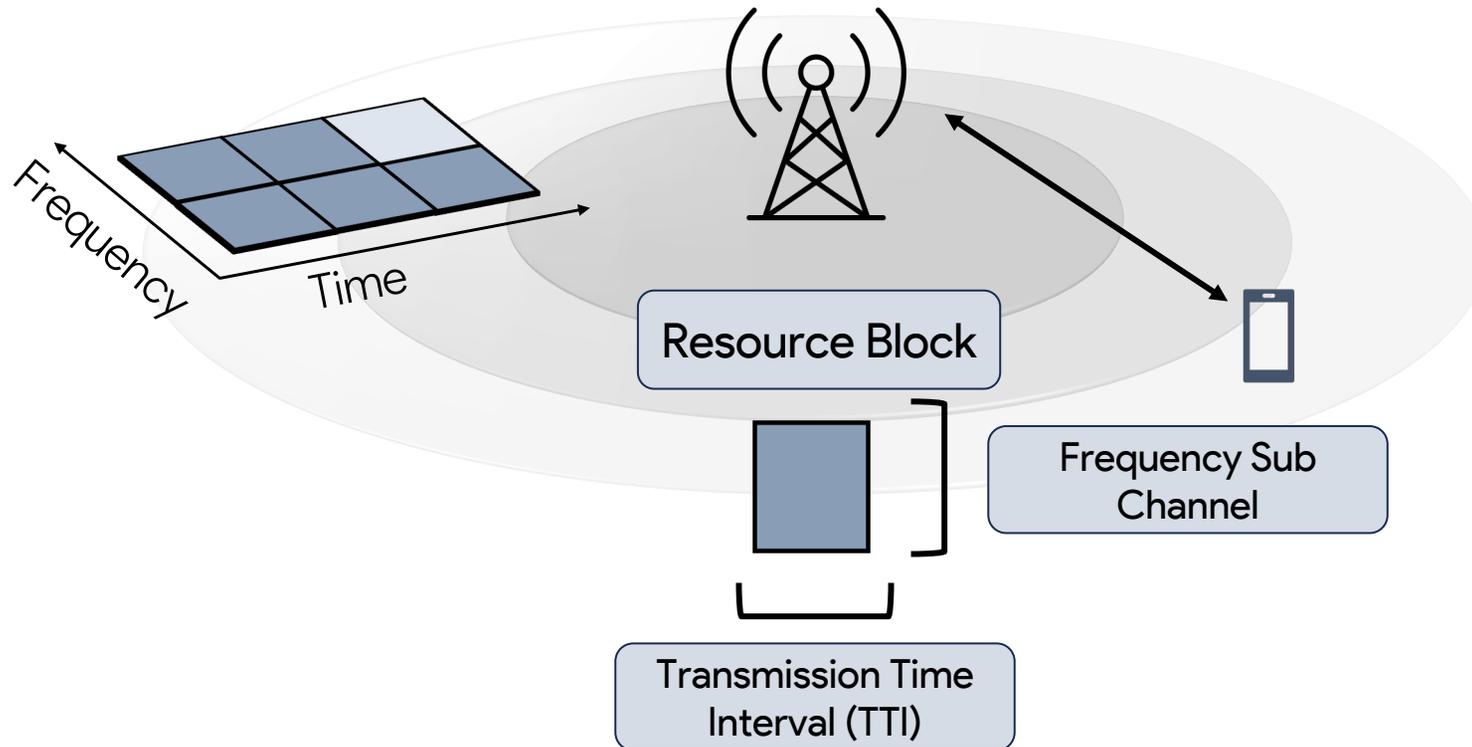
Radio Access Network (RAN)



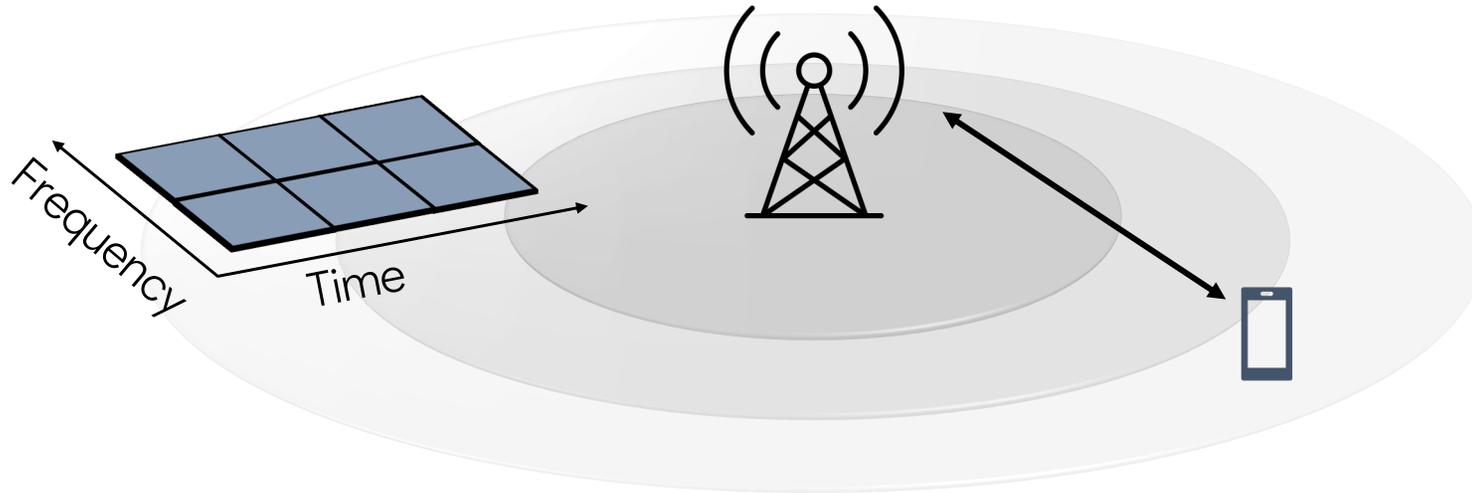
Resource Allocation at RAN



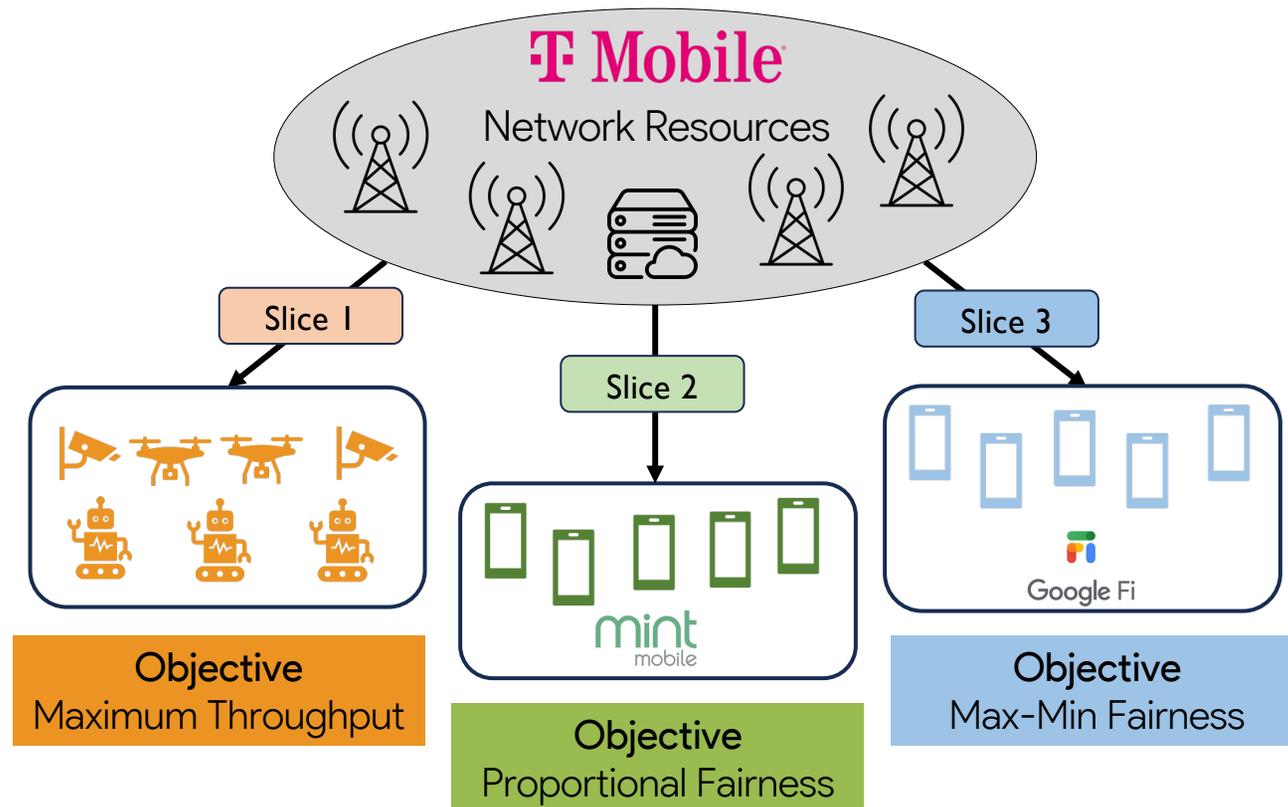
Resource Allocation at RAN



Resource Allocation at RAN

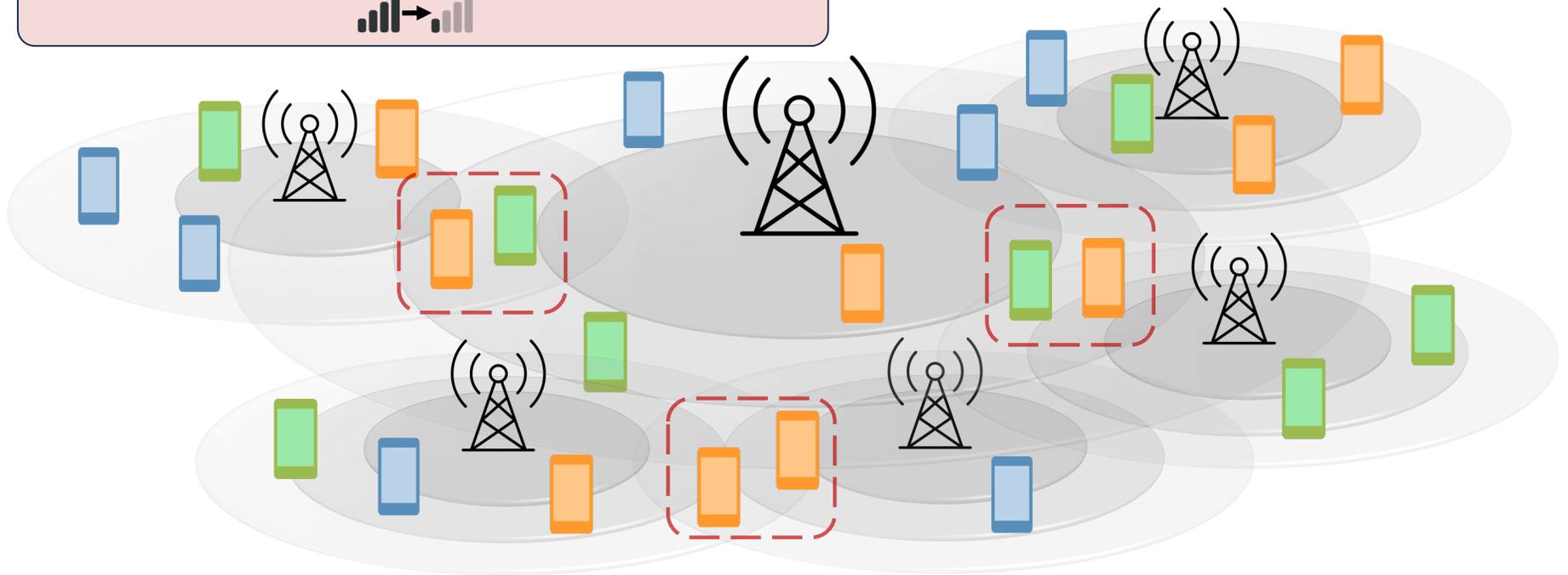


Radio Access Network (RAN) Slicing

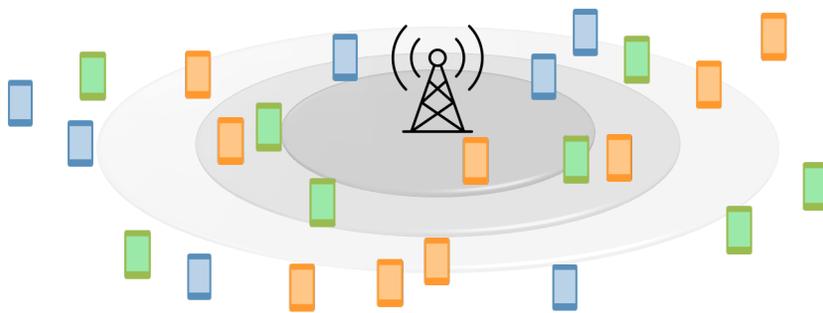


Multi Cell Deployments & Interference

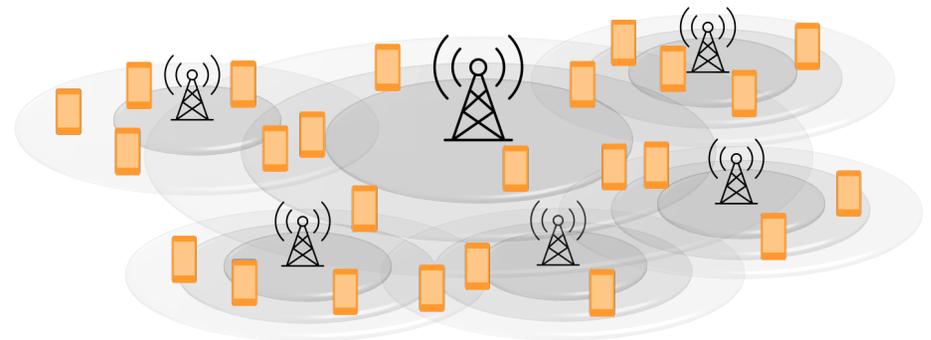
Users in overlapping coverage range are prone to interference



Background for RAN Resource Allocation

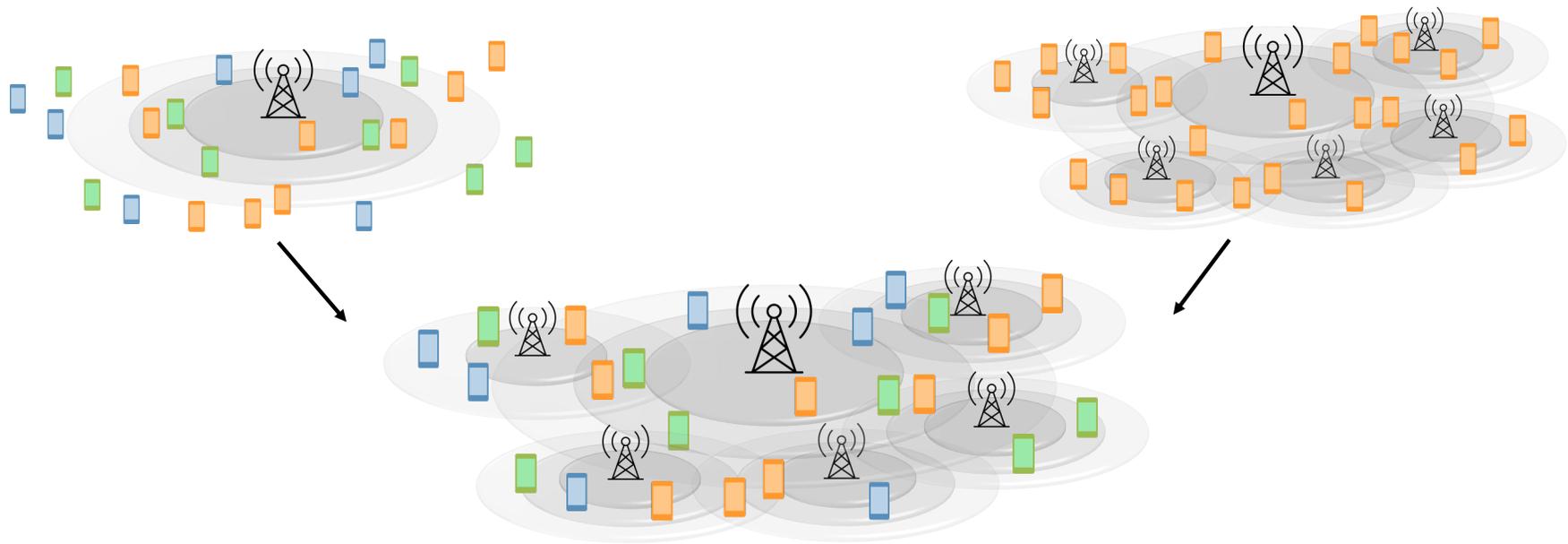


Resource Allocation for RAN Slicing
in Single Cell Deployments



Multi Cell Interference Management
(without RAN Slicing)

Our work: RadioNinja

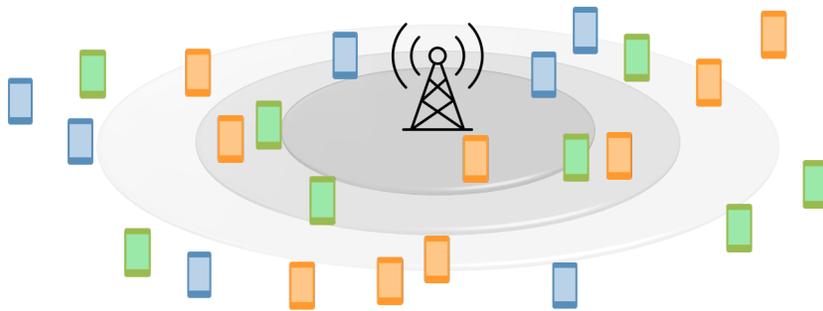


Resource Allocation for RAN Slicing while managing Interference in Multi Cell Deployments

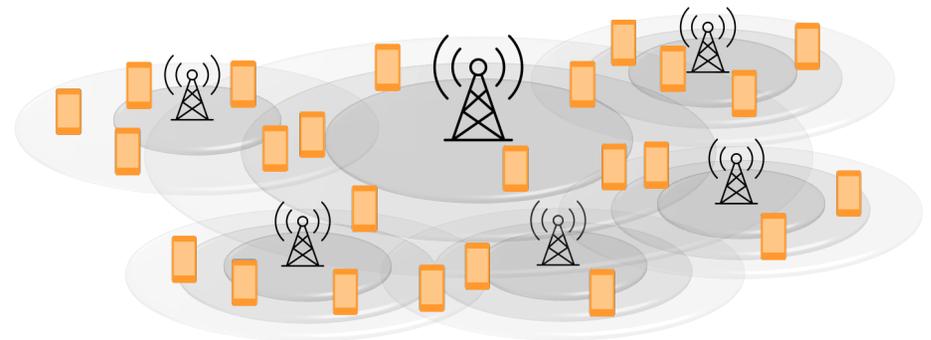
Outline

- Background
 - RAN slicing
 - Interference management through muting
- Interference management with slicing
- Our system: RadioNinja

Background for RAN Resource Allocation

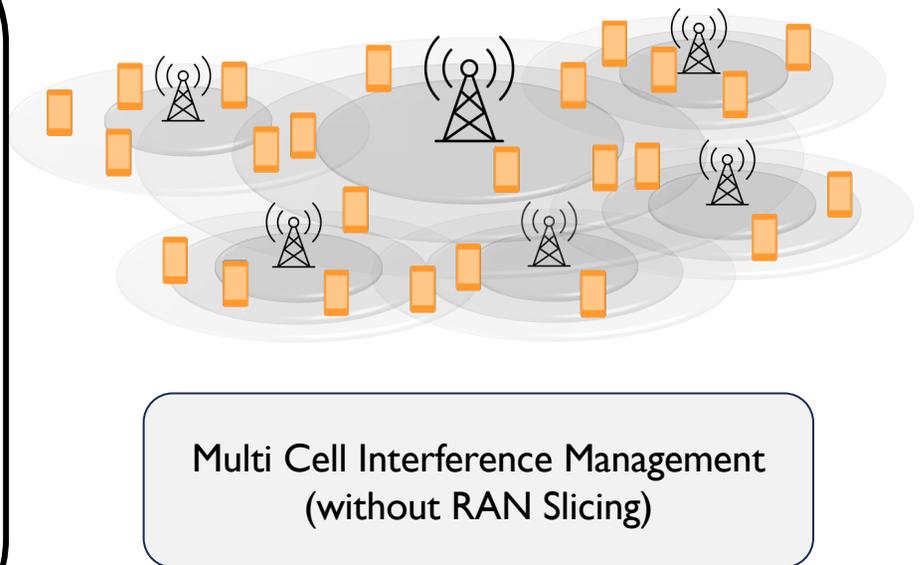


Resource Allocation for RAN Slicing
in Single Cell Deployments

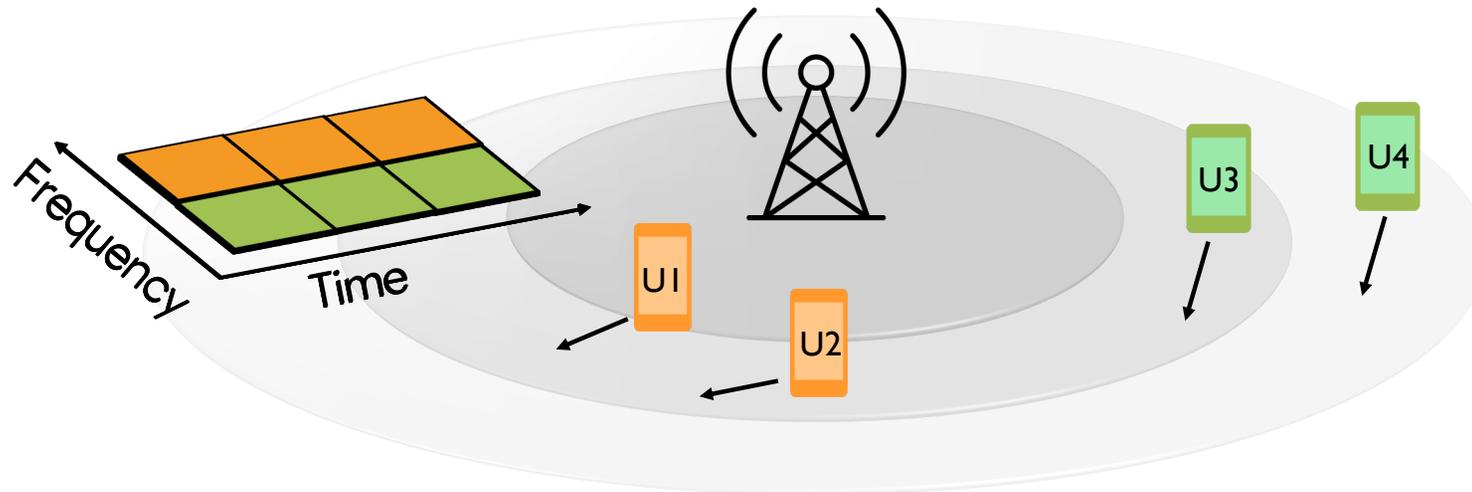


Multi Cell Interference Management
(without RAN Slicing)

Background for RAN Resource Allocation



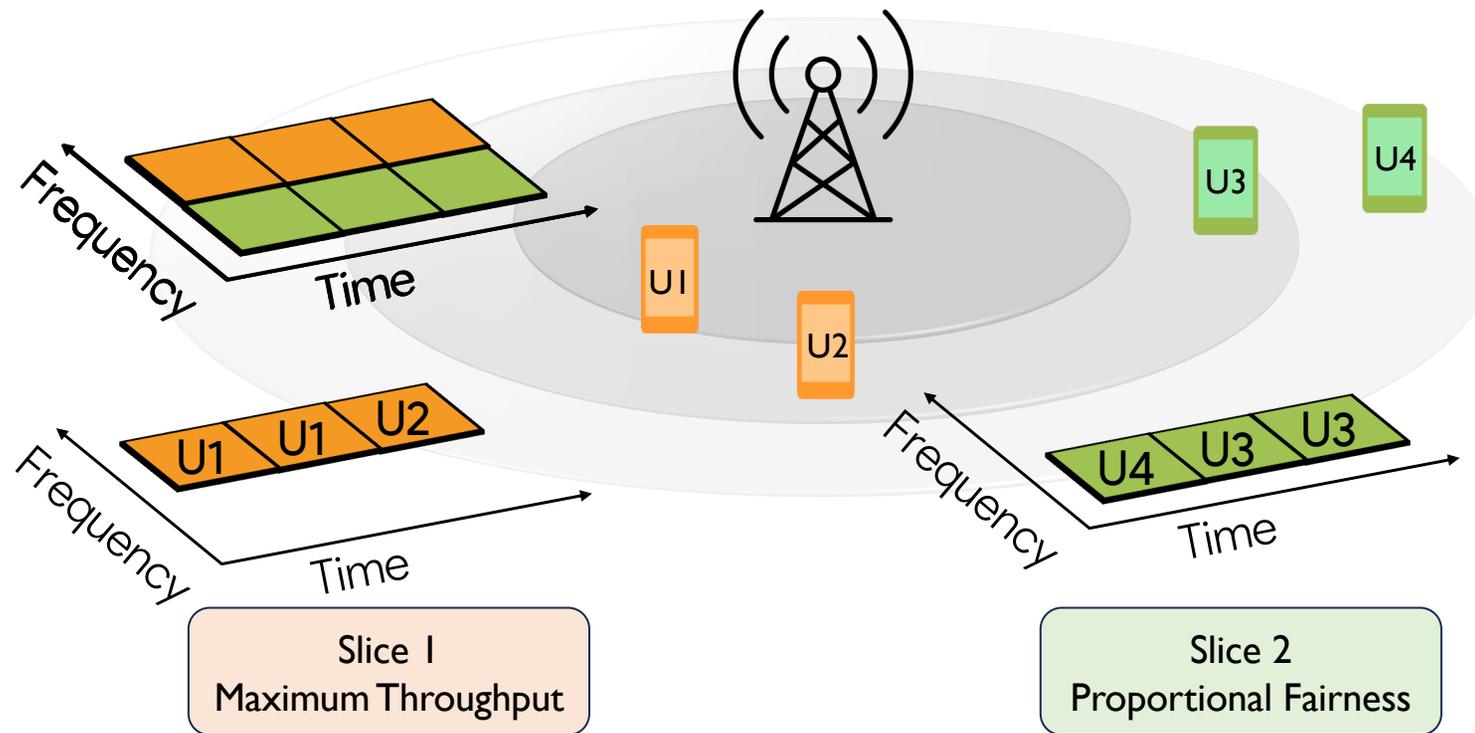
Resource Allocation with RAN Slicing



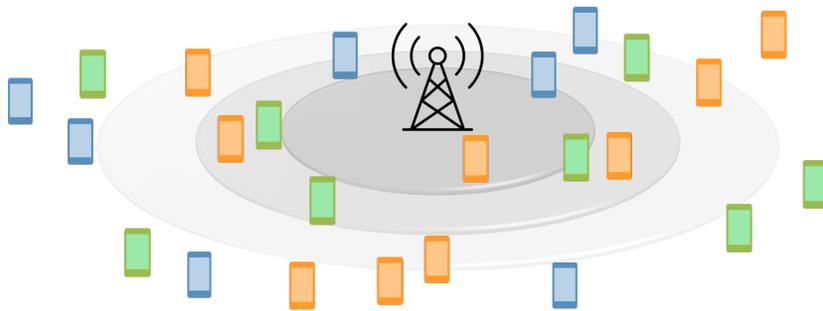
Slice 1
Maximum Throughput

Slice 2
Proportional Fairness

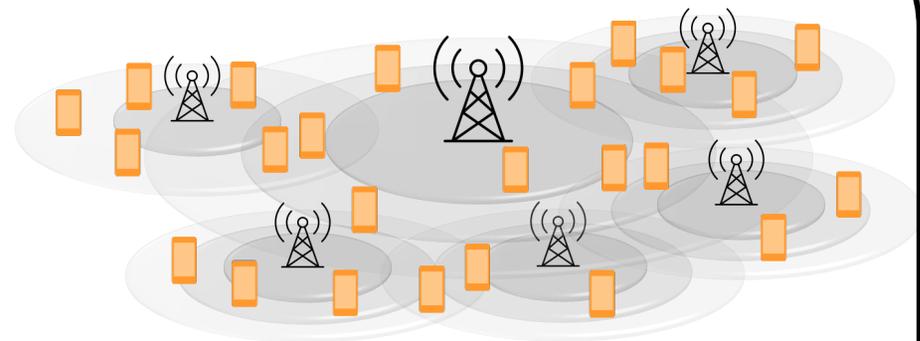
Resource Allocation with RAN Slicing



Background for RAN Resource Allocation

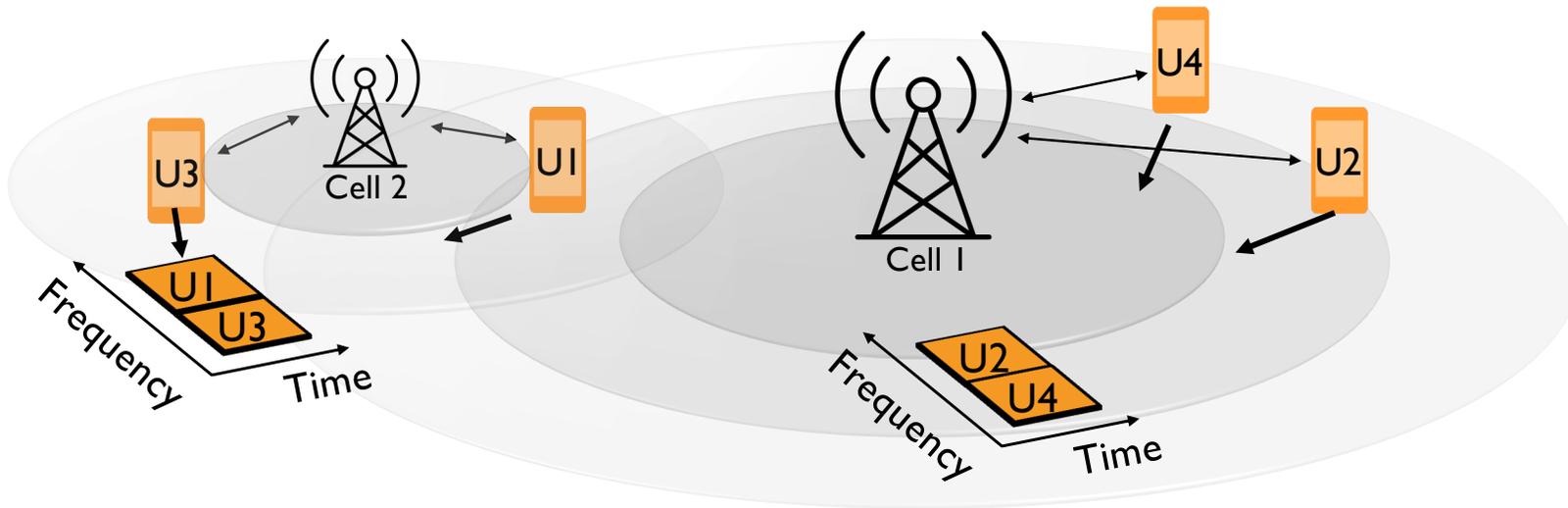


Resource Allocation for RAN Slicing
in Single Cell Deployments

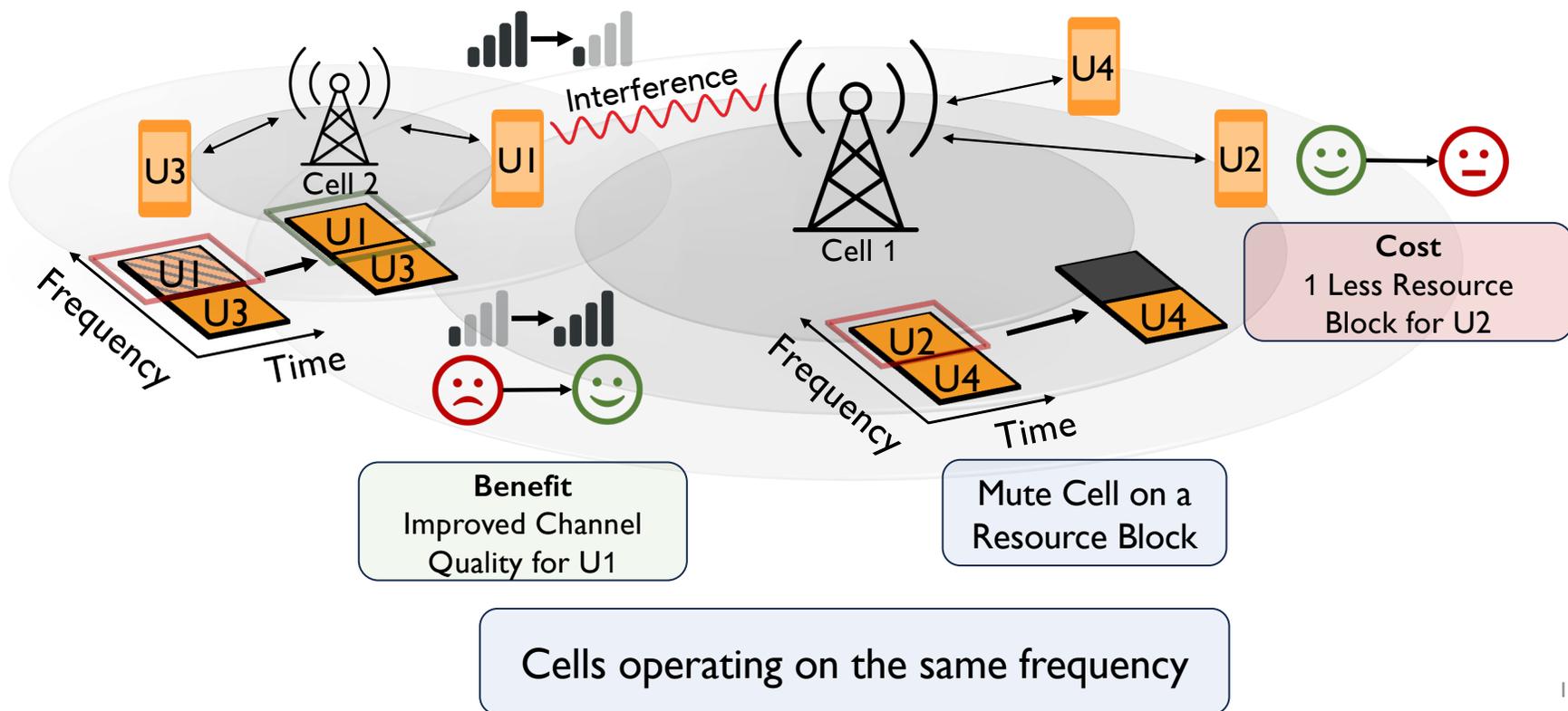


Multi Cell Interference Management
(without RAN Slicing)

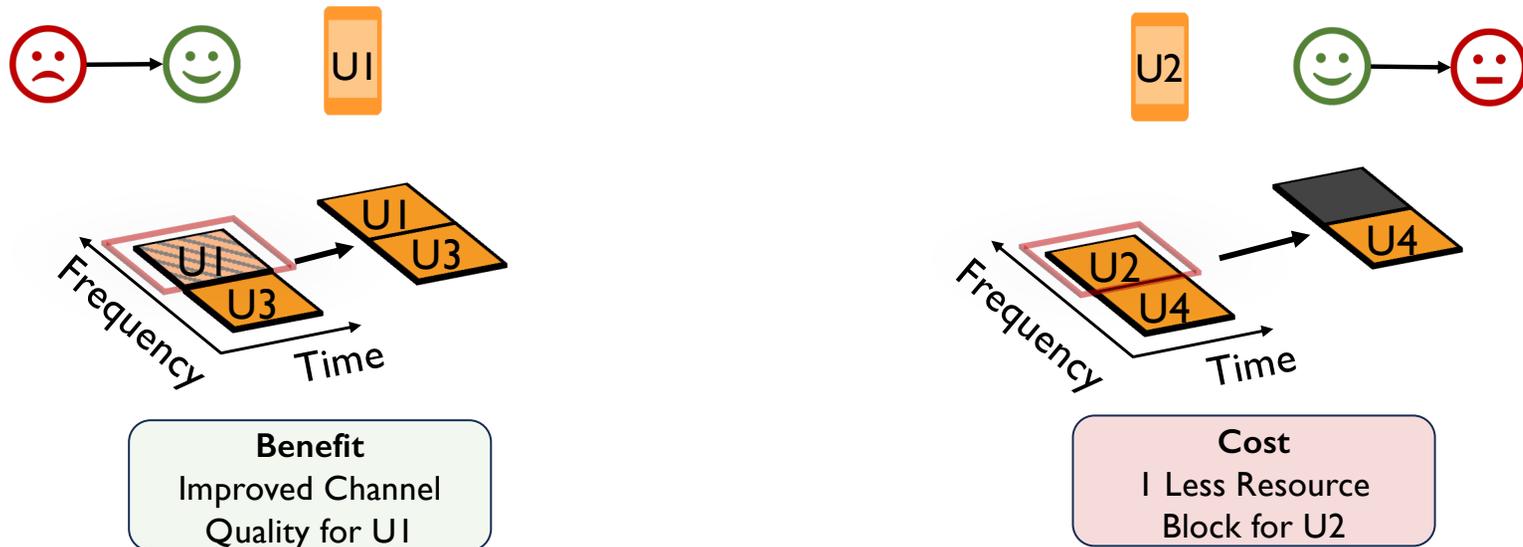
Interference in Multi Cell Deployments



Managing interference in Multi Cell Deployments

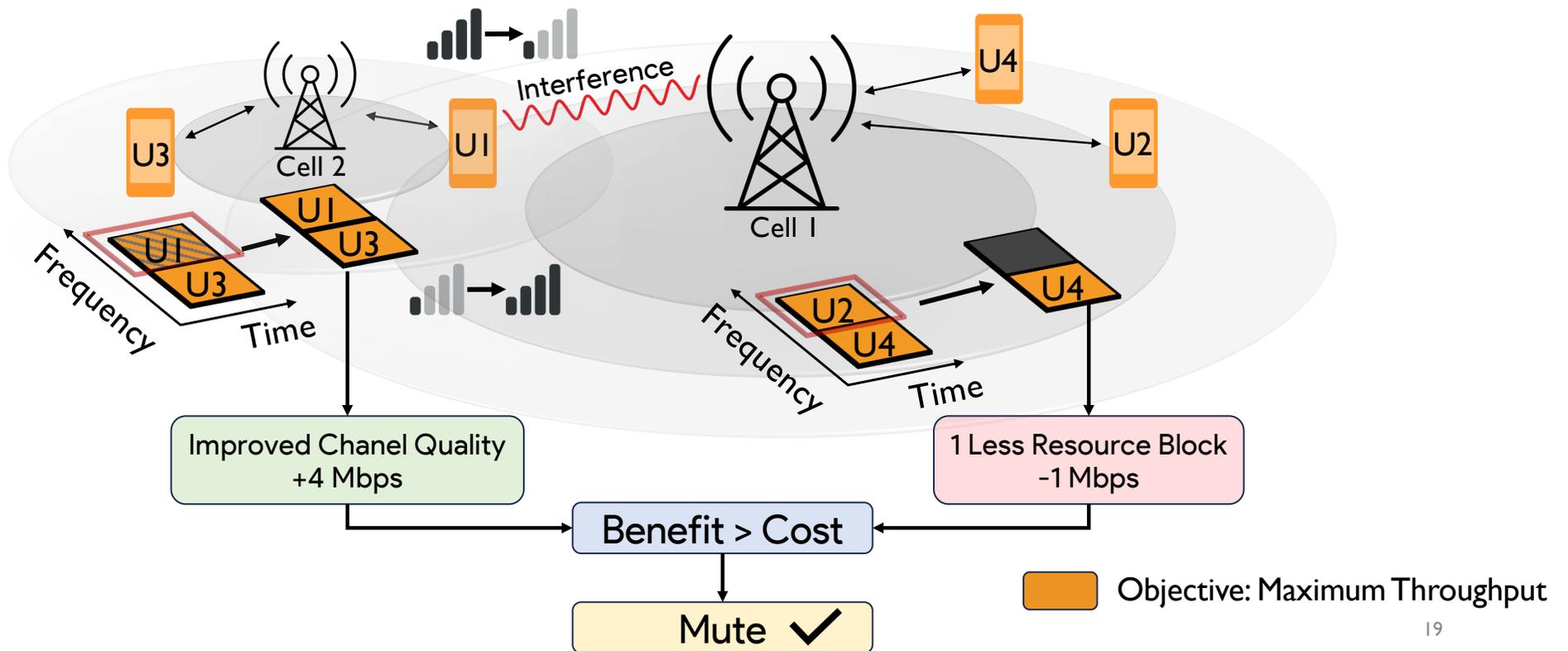


Reasoning about a muting decision



- How do we compare **benefit** versus **cost** across different users?
- Analogous to multi tenant resource allocation problems in systems

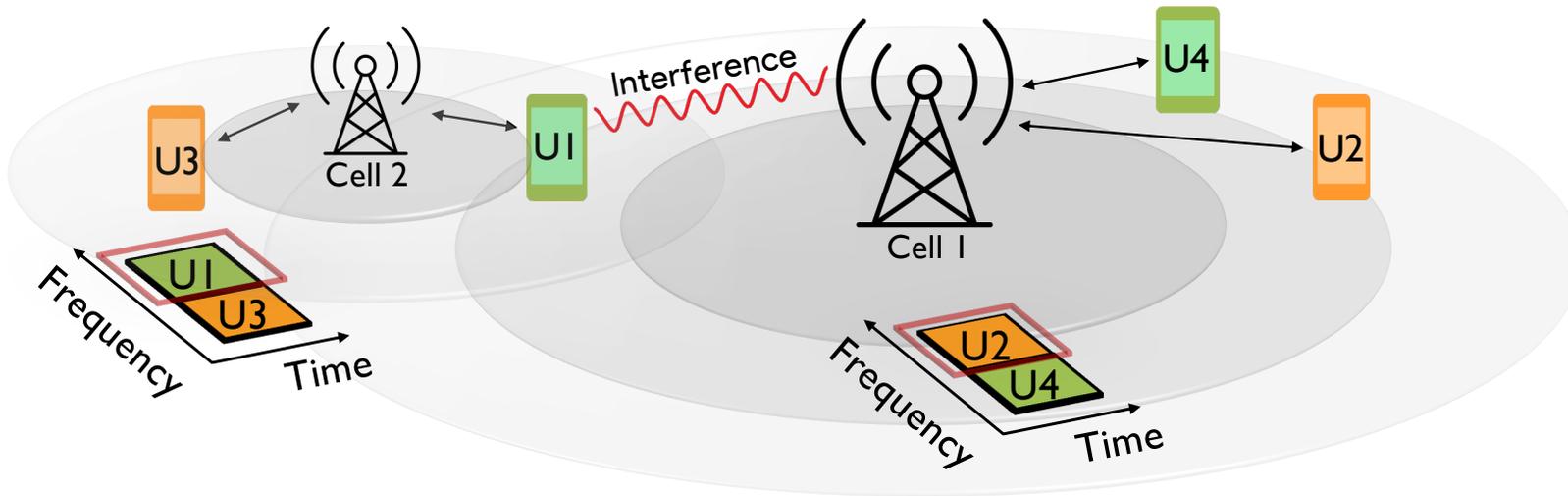
Muting without slicing



Outline

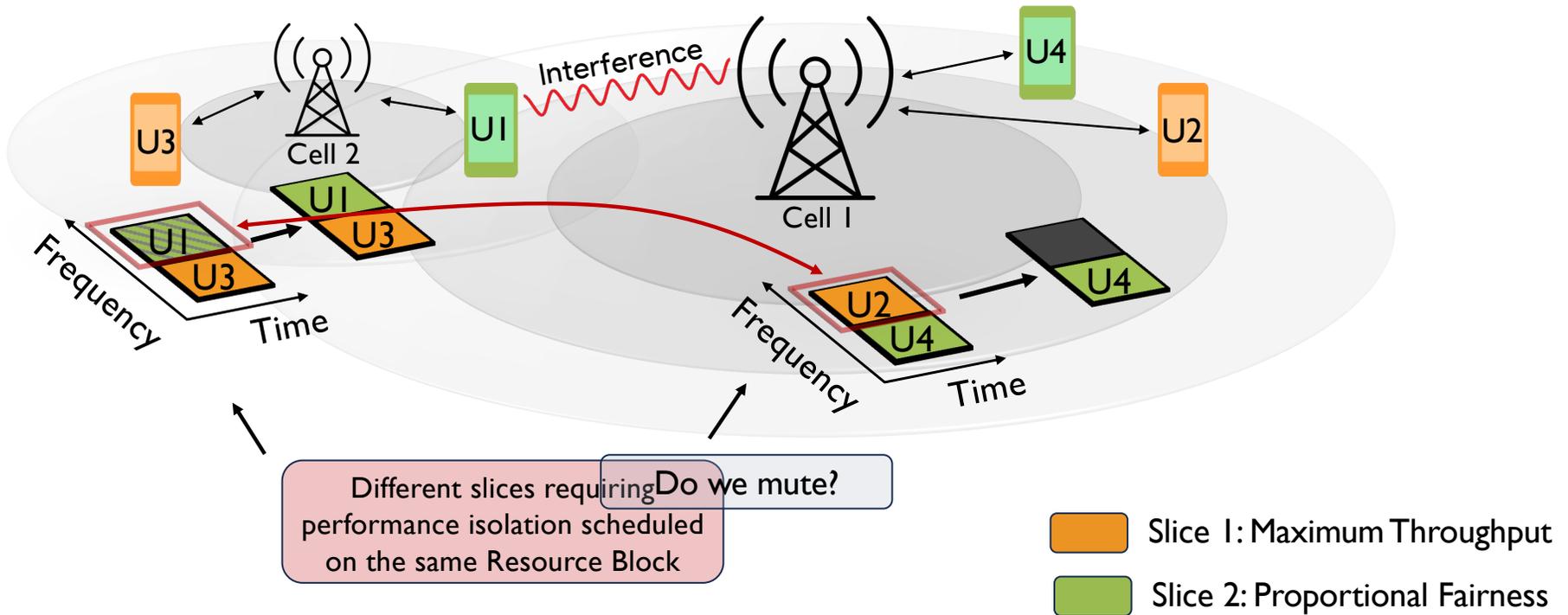
- Background
 - RAN resource allocation
 - Interference management
- Muting with Slicing
- Our system: RadioNinja

Muting with slicing

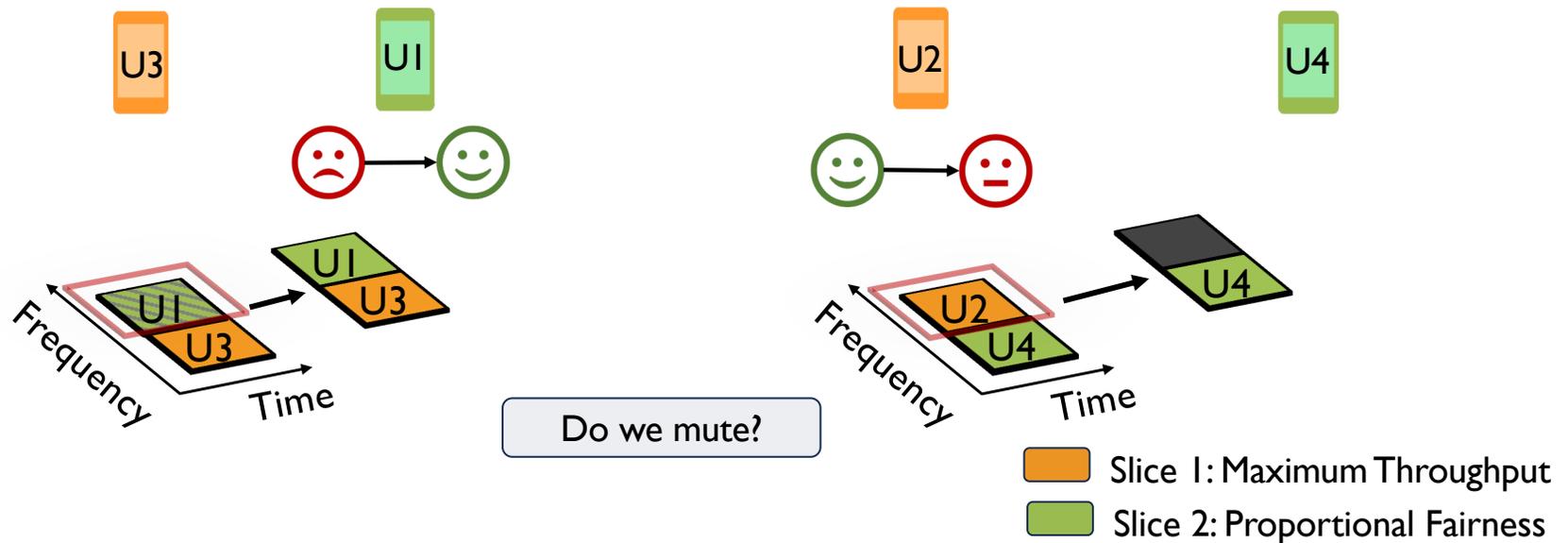


-  Slice 1: Maximum Throughput
-  Slice 2: Proportional Fairness

Muting with slicing



Reasoning about a muting decision with slicing

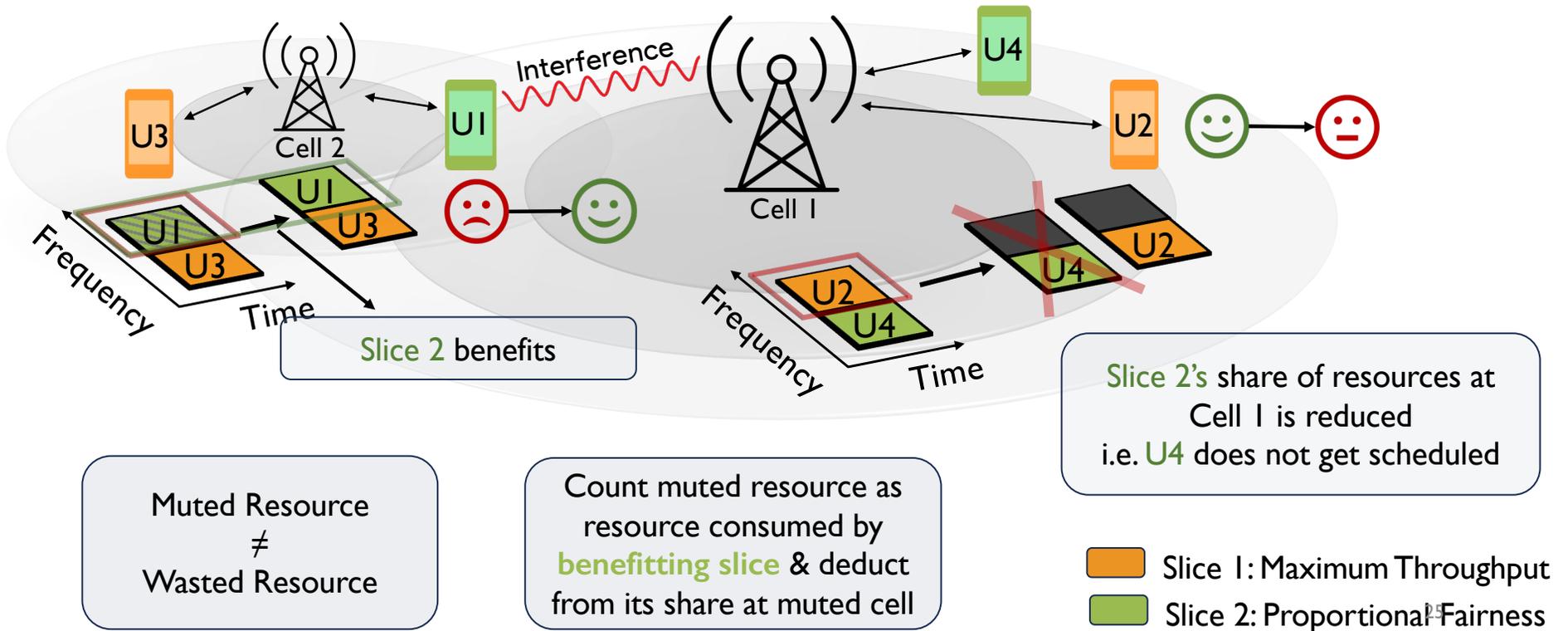


- Benefit **Slice 2** at expense of **Slice 1**? Violates Performance Isolation!
- How do we make decisions across different, possibly incomparable objectives?

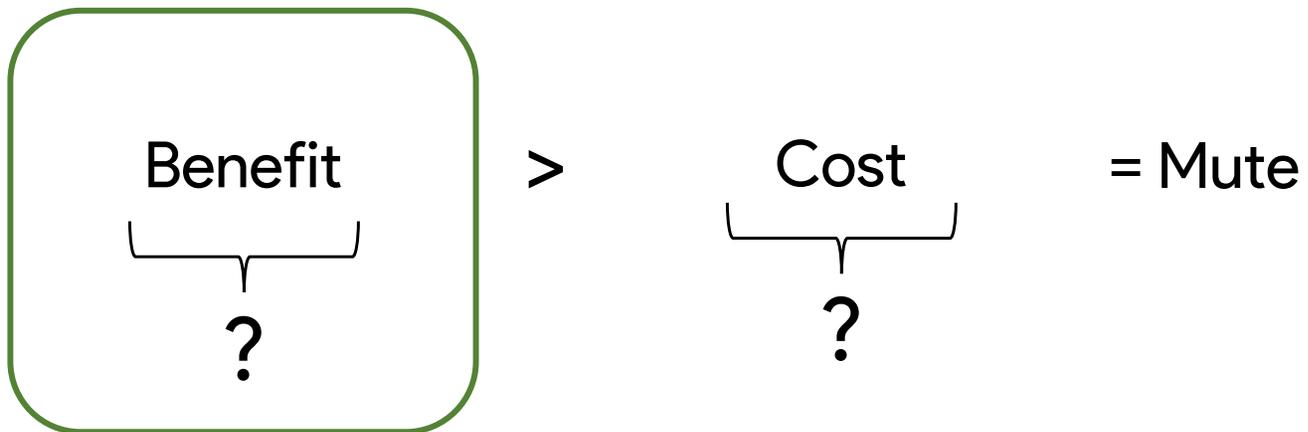
Outline

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 - Interference management
- Muting with Slicing
- Our system: RadioNinja

Key Insight: fine-grained accountability of muted resource



Deciding when to Mute

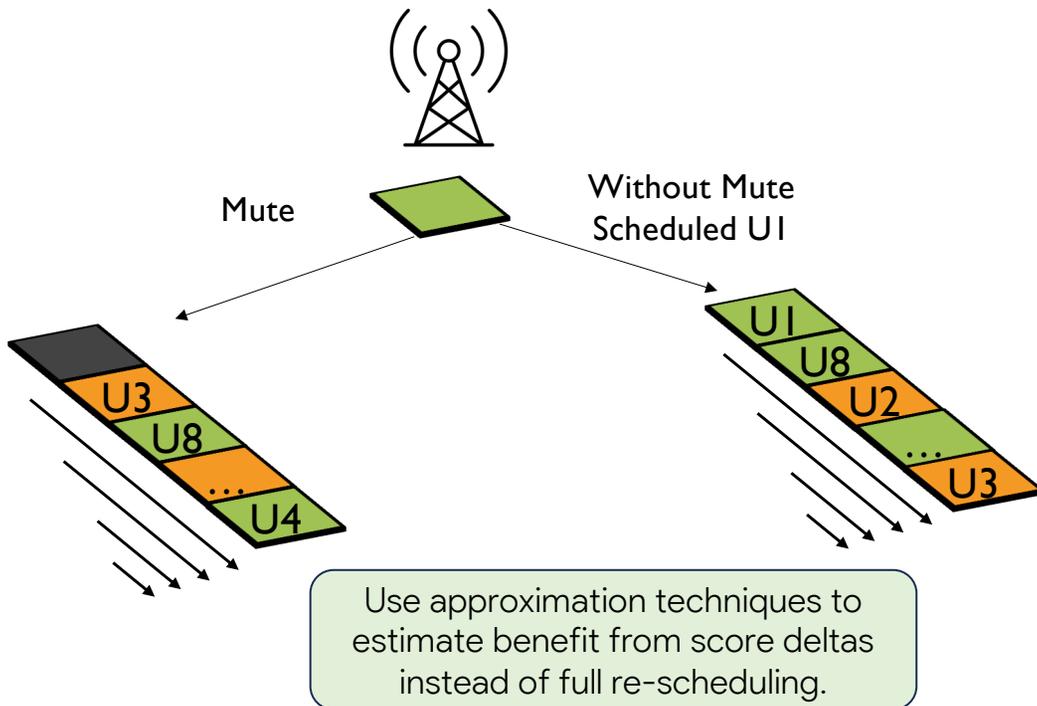


Calculating benefit is hard

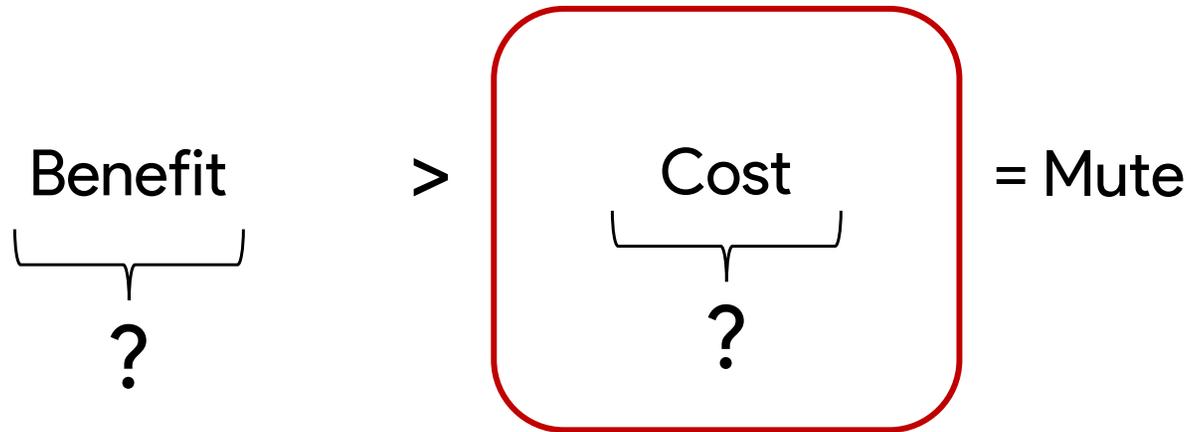
True Benefit is counterfactual: need to know what allocation would look like without muting vs. with muting

Muting creates ripple effects, altering allocation of remaining resources

Re-run complete scheduler for each resource.
Prohibitively expensive under sub-ms RAN Scheduling deadlines



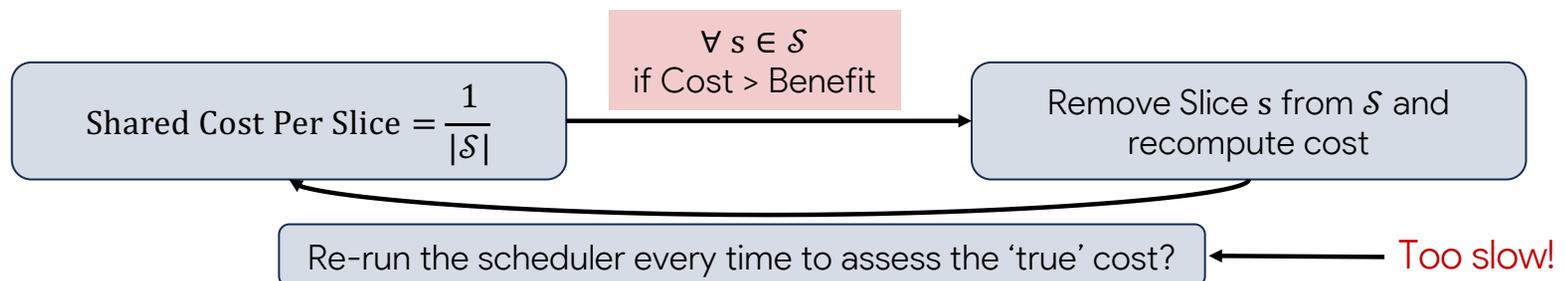
Deciding when to Mute



Chicken-and-egg in cost attribution

- Fairness = cost of muting shared amongst all slices benefitting \rightarrow participating in muting
- Cost based on number of participating slices but slices make decision to participate based on cost.

- \mathcal{S} = Set of Slices benefitting from Muting
- Only slices where **benefit** > **cost** stay in $\mathcal{S} \rightarrow$ participate in muting



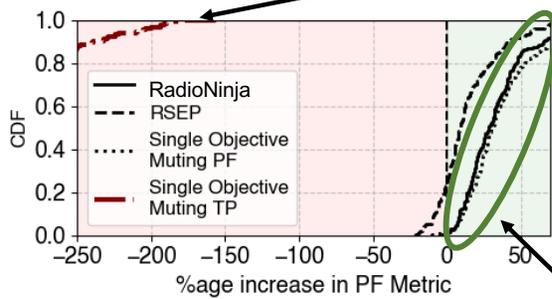
Approximate cost through a 'reference schedule', enabling fast cyclic evaluation of cost-benefit

Evaluation

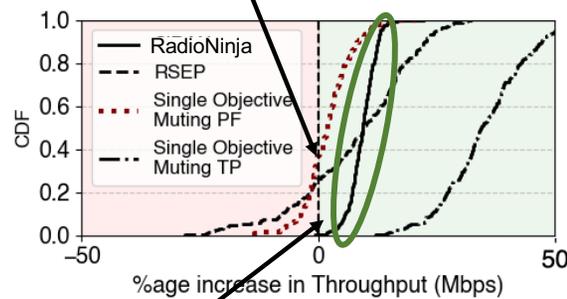
- Trace-driven simulations (real world cellular traces): **5 cells**, up to **250 users**, **12 slices**
- **Baseline:** *RadioSaber* — channel quality aware scheduler, **no interference management**
- **Comparisons:**
 - **SOM (Single-Objective Muting):** optimizes one global metric, agnostic of individual slice level objectives, violates per-slice objectives
 - **RSEP:** allocation of same-frequency across cells (naïve), ignore channel-quality variations

Evaluation

Aggregates all slices into a single optimization + Misaligned objectives lead to suboptimal decisions = LOSS

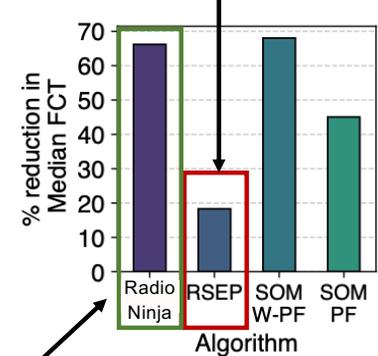


Fairness Slices



Max Throughput Slices

Channel Quality Unaware allocation leads to lower spectrum efficiency hence low performance



Weighted Fairness (Web Flow Traffic)

Key result: RadioNinja consistently improves on individual slice level metrics, **preserves slice isolation** with no slice worse off (zero loss)

Conclusion

Multi Tenant Interference Management for RAN Slicing

- Challenge 1 – How to ensure performance isolation across slices?
 - Challenge 2 – How to jointly optimize unique objectives across competing slices (tenants)?
 - Challenge 3 – How to do it fast?
- Do Per Slice Cost-Benefit Tradeoff without any aggregation across slices
- Utilize approximation technique to calculate cost/benefit
- RadioNinja provides 20-60% improvement in corresponding slice objectives (fairness, throughput, flow completion time, etc.)