

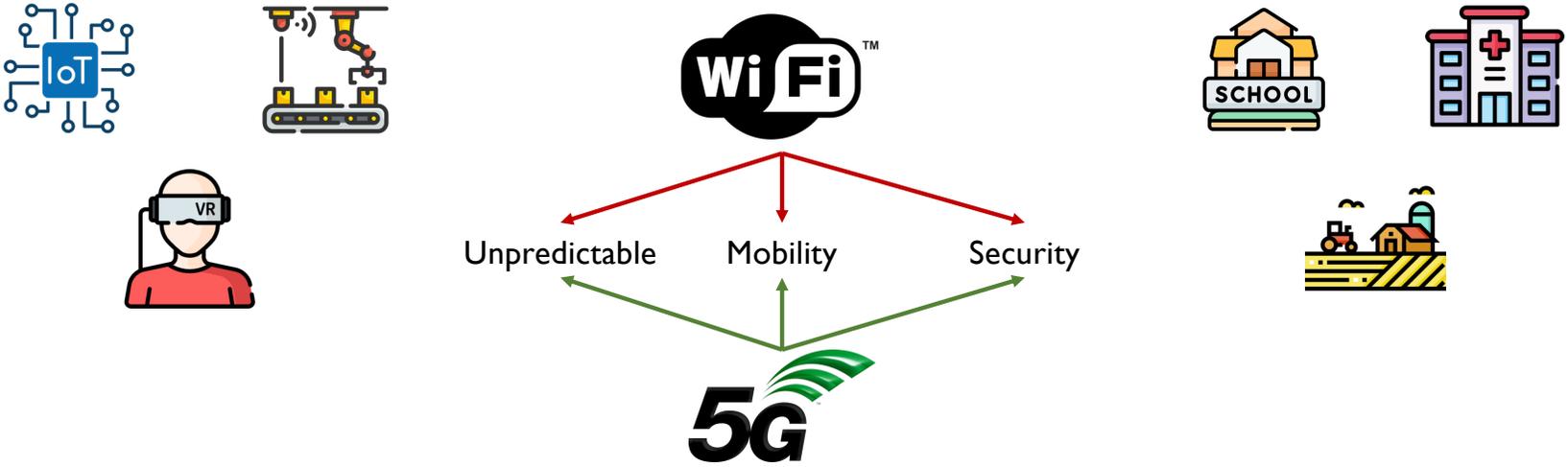
Saving Private Cellular: The Coordination Vacuum in CBRS

Taimoor Tariq, Radhika Mittal



Emerging Connectivity Needs

- Modern private enterprises increasingly rely on reliable wireless connectivity



Cellular has been inaccessible for private enterprises



**Verizon, AT&T and T-Mobile
dominate \$81 billion 5G
spectrum auction**



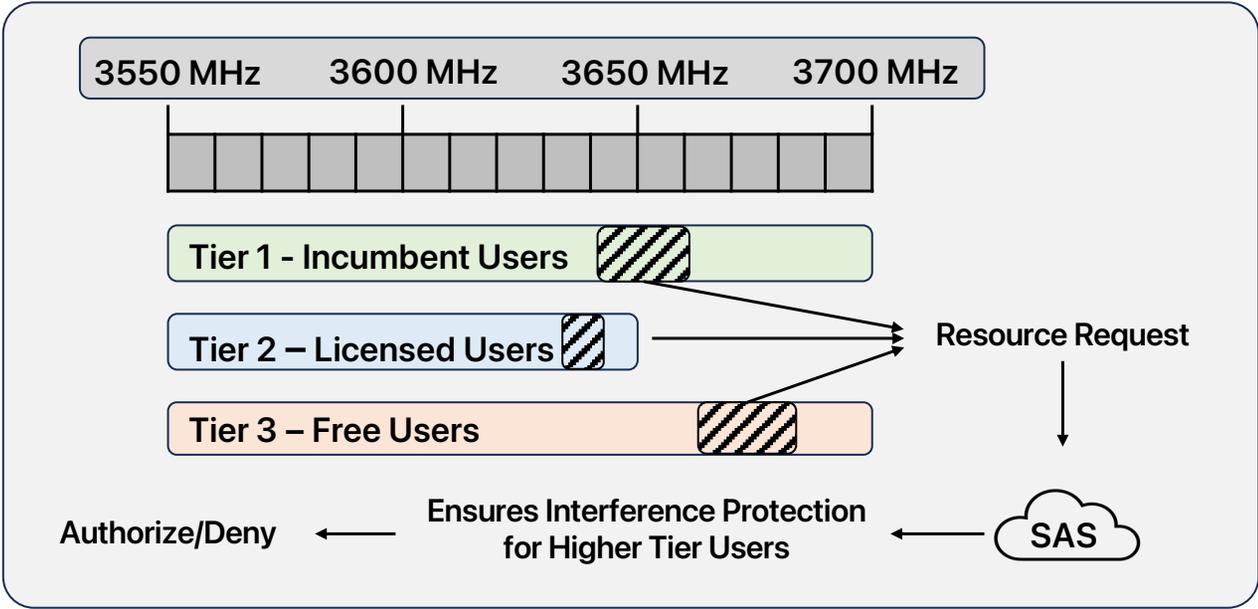
RESEARCH — 22 APR, 2021

**US C-band auction becomes
world's costliest mid-band 5G
auction yet**



Barrier to entry too high!

CBRS: Lowering the Barrier to Private Cellular



Growing Momentum for CBRS Deployments

ICYMI: John Deere Leverages



JOHN DEERE



cradlepoint



TOYOTA



BMW

CBRS-based Private 5G Network Enhances Operations in South Carolina Plant



Tulsa International

CBRS Helps Standard



DFW

DFW Airport Use Move Into



PORT OF OAKLAND

Port of Oakland Uses CBRS to Improve Yard Operations



POARCH CREEK INDIANS



YAKAMA NATION

POARCH BAND OF CRE
Achieves Digital Solve

Yakama Nation Deploys CBRS Network to Bridge Digital Divide



Stanford

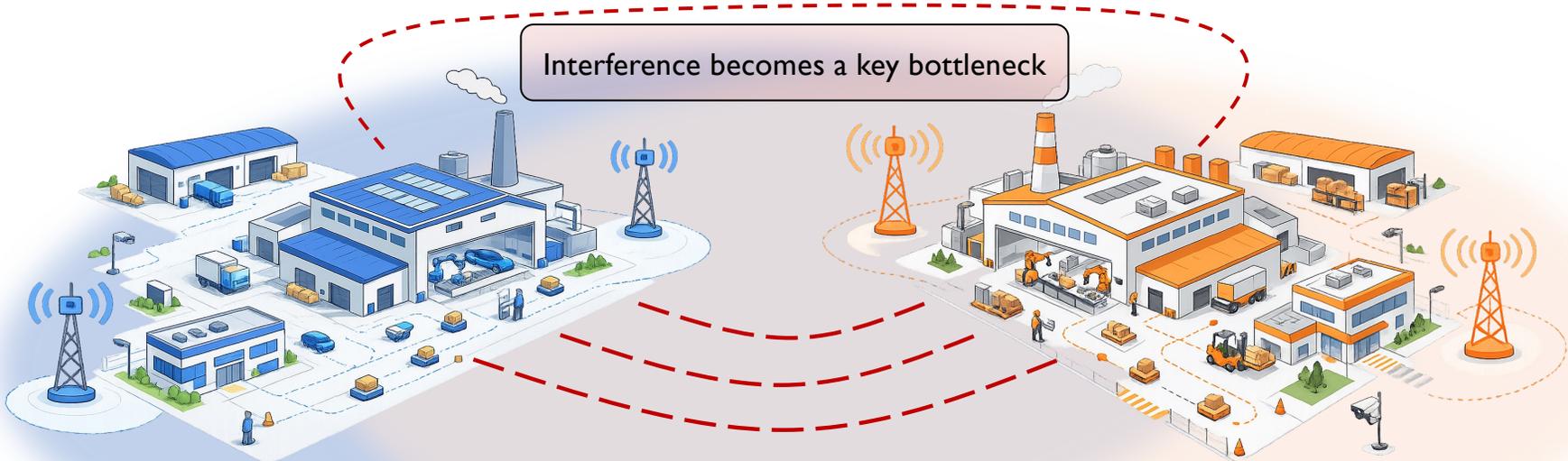


JACKSON PUBLIC SCHOOLS

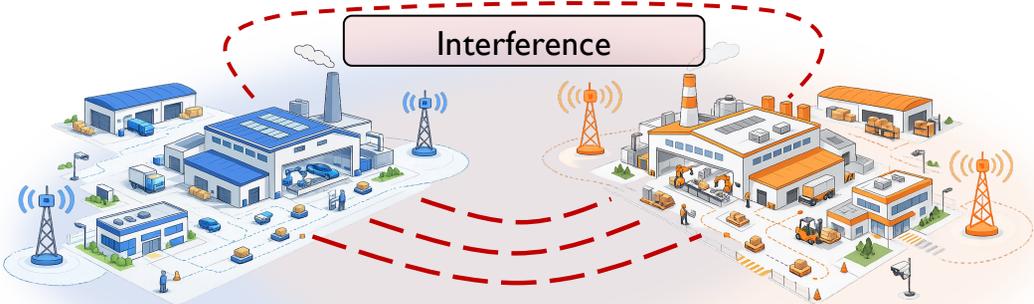
Jackson Public Schools Powers Learning with CBRS Networks

Jackson Public Schools in Mississippi is leveraging CBRS to serve nearly 17,000 students across 36 schools spanning 104 square

CBRS Interference in the Wild



CBRS Interference in the Wild



Poor signal quality

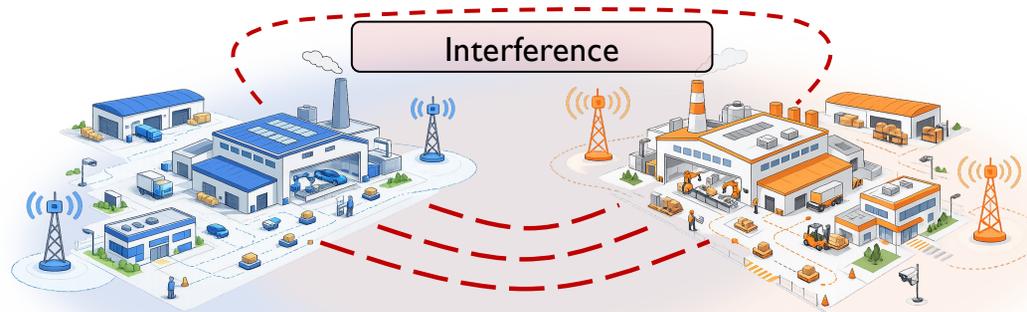


Dropped connections



Violated SLOs

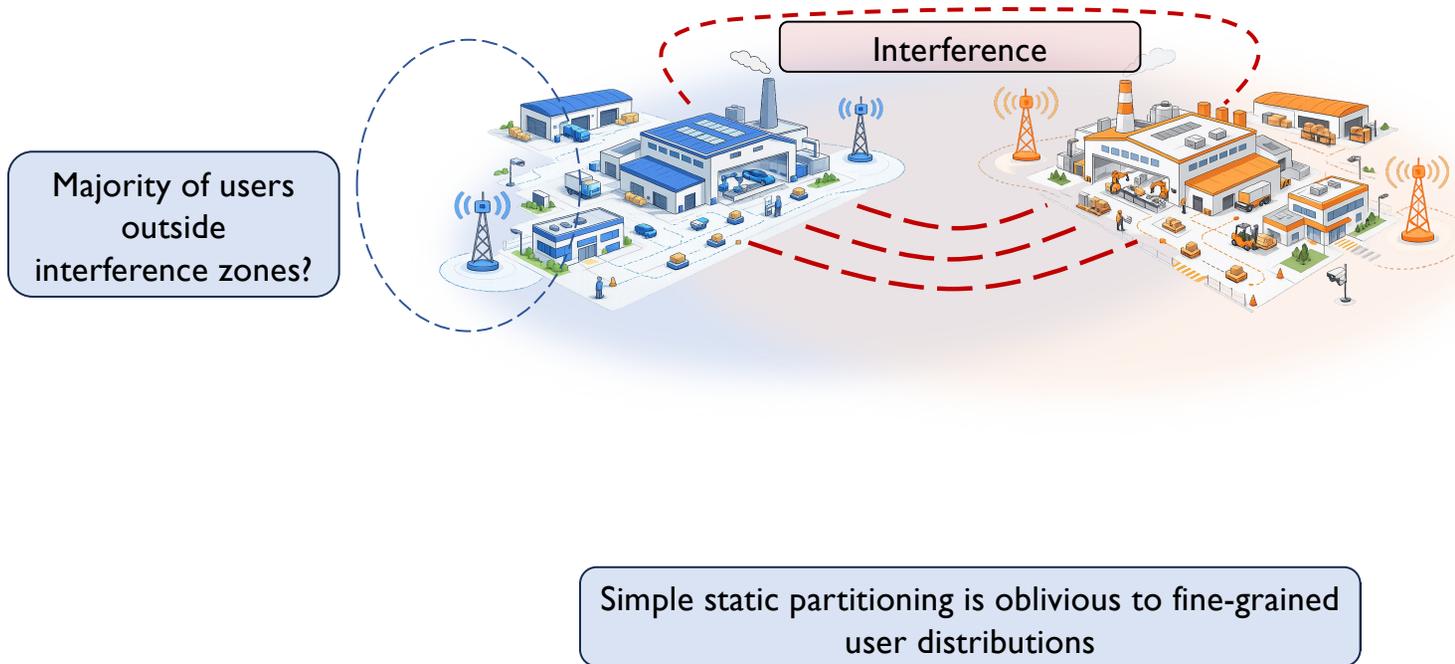
CBRS Interference in the Wild



“General Authorized Access Users shall have no expectation of interference protection from other General Authorized Access Users...” – FCC Specs Chapter 96.35 (d)

“... operators are expected to cooperate and resolve interference problems through technological solutions or by other mutually satisfactory arrangements...” – FCC Specs Chapter 96.35 (e)

Static partitions and its inefficiency



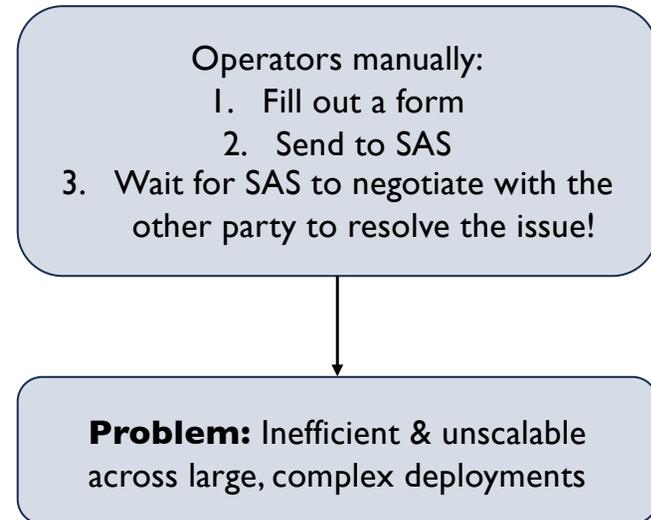
Logistical inefficiency

7.1 Interference Report Form

This is the primary form for generating a GCA Frequency plan. It is also useful for reporting information about unauthorized users to the FCC for investigation.

| Summary | | | | | |
|---|---|-----------------------------|---------------------------------------|----------------------------|---|
| [REQUIRED] Reporter / Contact Information | Name | Company | Email | Phone Number(s) | |
| [REQUIRED] Devices experiencing interference (CBSID IDs, FCC ID, or Serial Numbers) | Please list the CBSIDs and the frequencies for those CBSIDs that are experiencing interference, one per line. Please do NOT put CBSID IDs of devices that you suspect are causing interference in this section. If in your investigation you suspect or have determined another operator and/or CBSID causing the interference, please feel free to provide that information in the section below, Description of Interference. | | | | |
| | CBSID ID or FCC ID / Serial Number | Frequencies (Lower - Upper) | Principal Subordinate SFG (CCG) group | Spectrum Reuse (ICG) group | Device / Deployment notes (Ex. CPE, eNB, gNB) |
| | 1 | | | | |
| | 2 | | | | |
| | 3 | | | | |
| | 4 | | | | |
| | 5 | | | | |
| | 6 | | | | |
| | 7 | | | | |
| | 8 | | | | |
| | 9 | | | | |
| [REQUIRED] Time period of interference | Start Date/Time | End Date/Time | | | |
| [REQUIRED] Total bandwidth desired | Bandwidth | Preferred Frequency | TDD Configuration | | |
| [OPTIONAL] Description of interference | Please provide any additional description or findings from your investigation that you can share. If you have spectrum scans for the CBSIDs experiencing interference that can be shared, please include them in separate page or attach them to your ticket. | | | | |

Table 2: Example interference report template



Desirable properties



Predictable Fairness

Benchmark: No user should be worse off than static partitioning



Dynamic Adaptation

Must adapt channel allocations to real-world interference conditions

Defining Fairness

For a shared public resource – how to reason about fairness?



User-based
Fairness

Opens room to gamification
Deploy more SIMs → Get higher share



Cell-based
Fairness

Good estimate of deployment scale
Financial barrier to gamification



Operator-based
Fairness

Ignores deployment scale

The recipe for an ideal system



True, Predictable Fairness

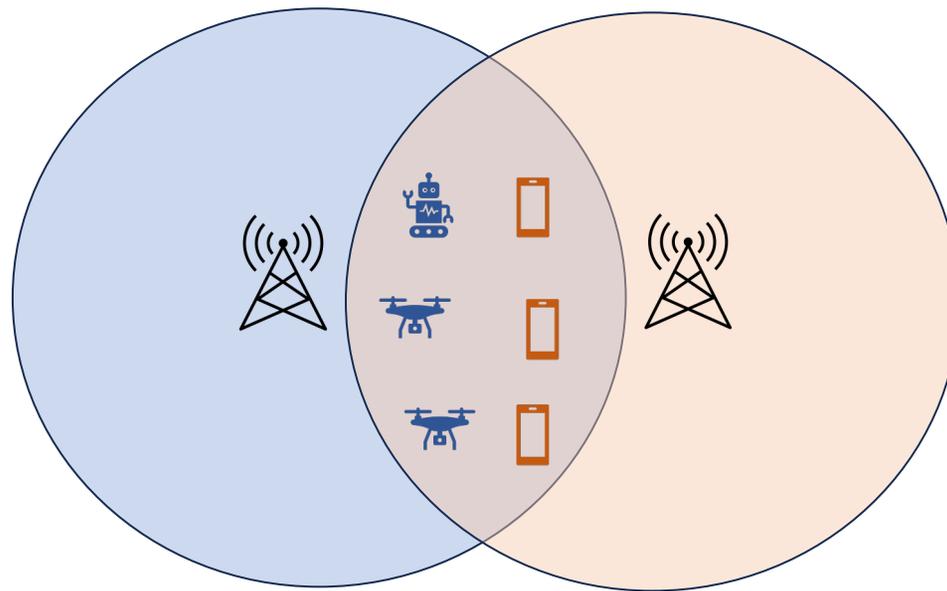
Benchmark: No user should be worse off than static partitioning



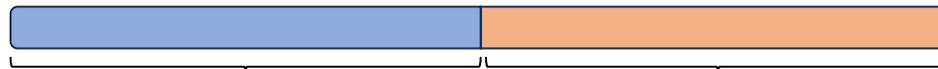
Dynamic Adaptation

Must adapt channel allocations to real, real-time interference and demand conditions

Beyond rigid partitions



Isolated for Blue

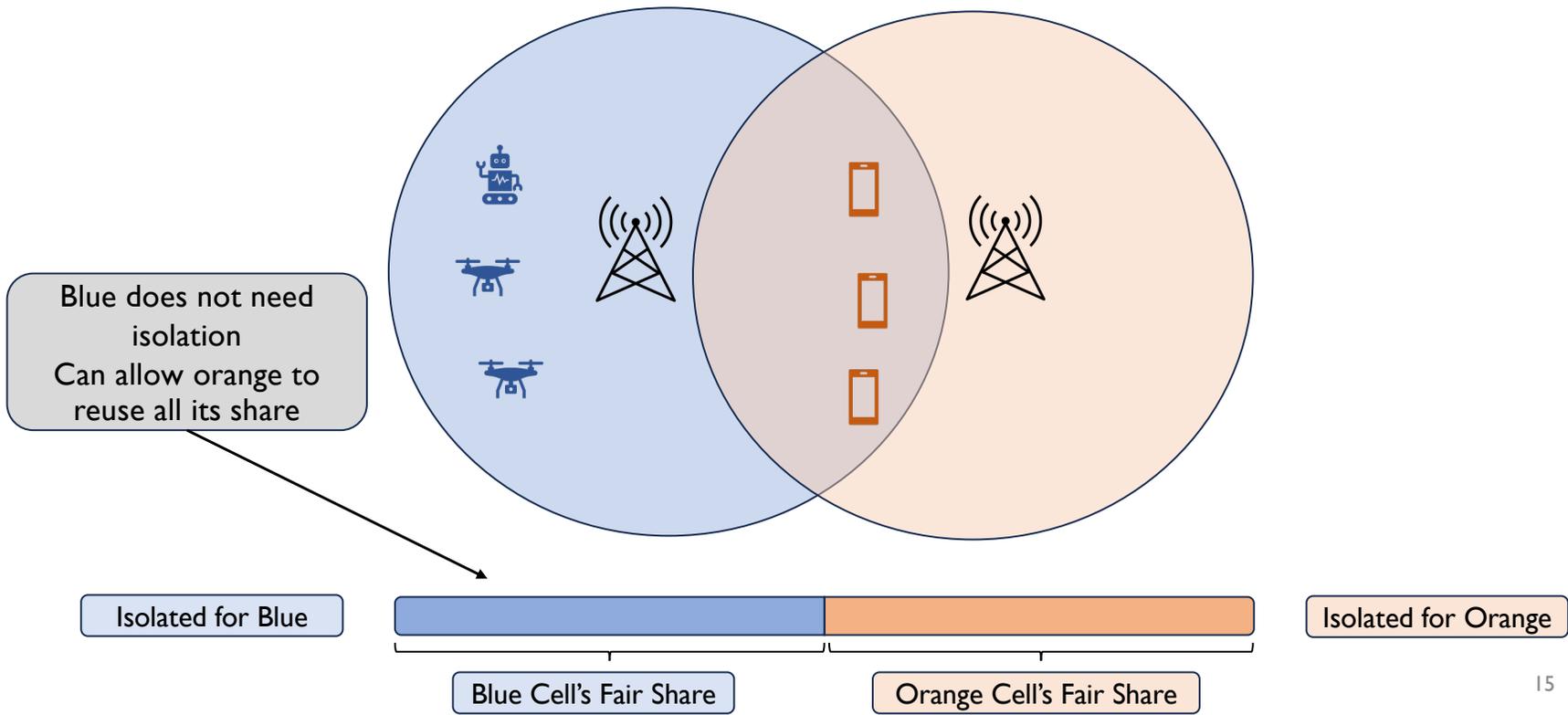


Blue Cell's Fair Share

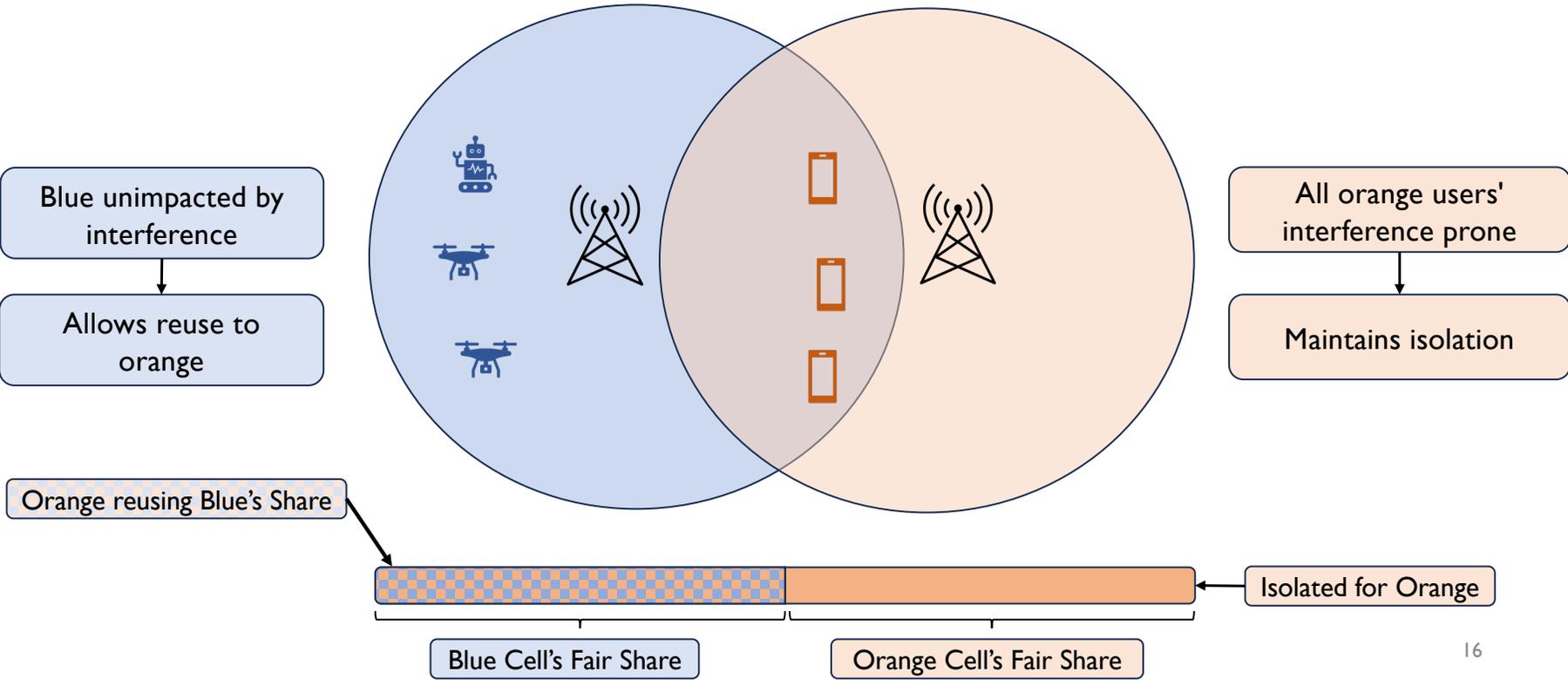
Orange Cell's Fair Share

Isolated for Orange

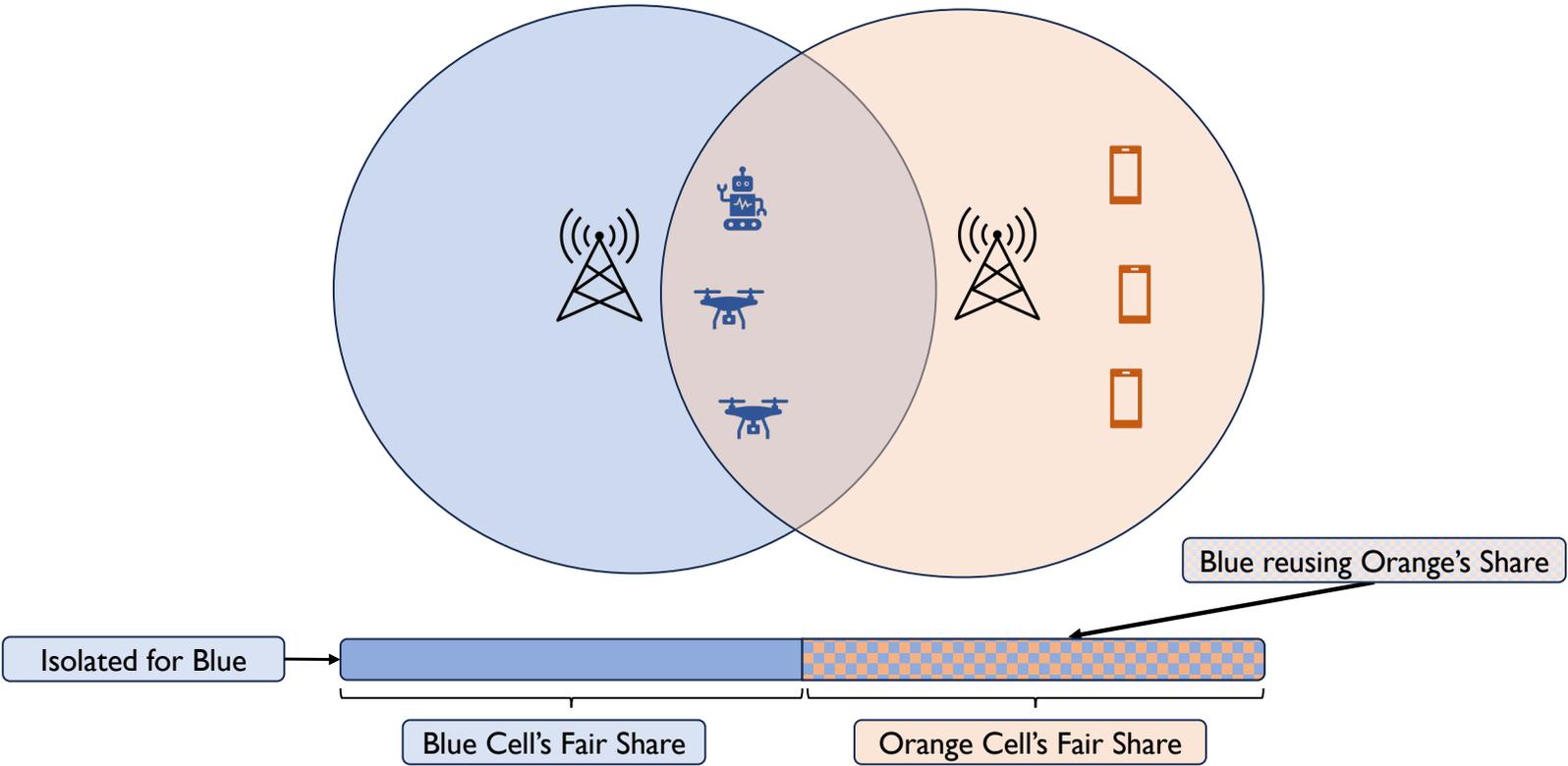
Beyond rigid partitions



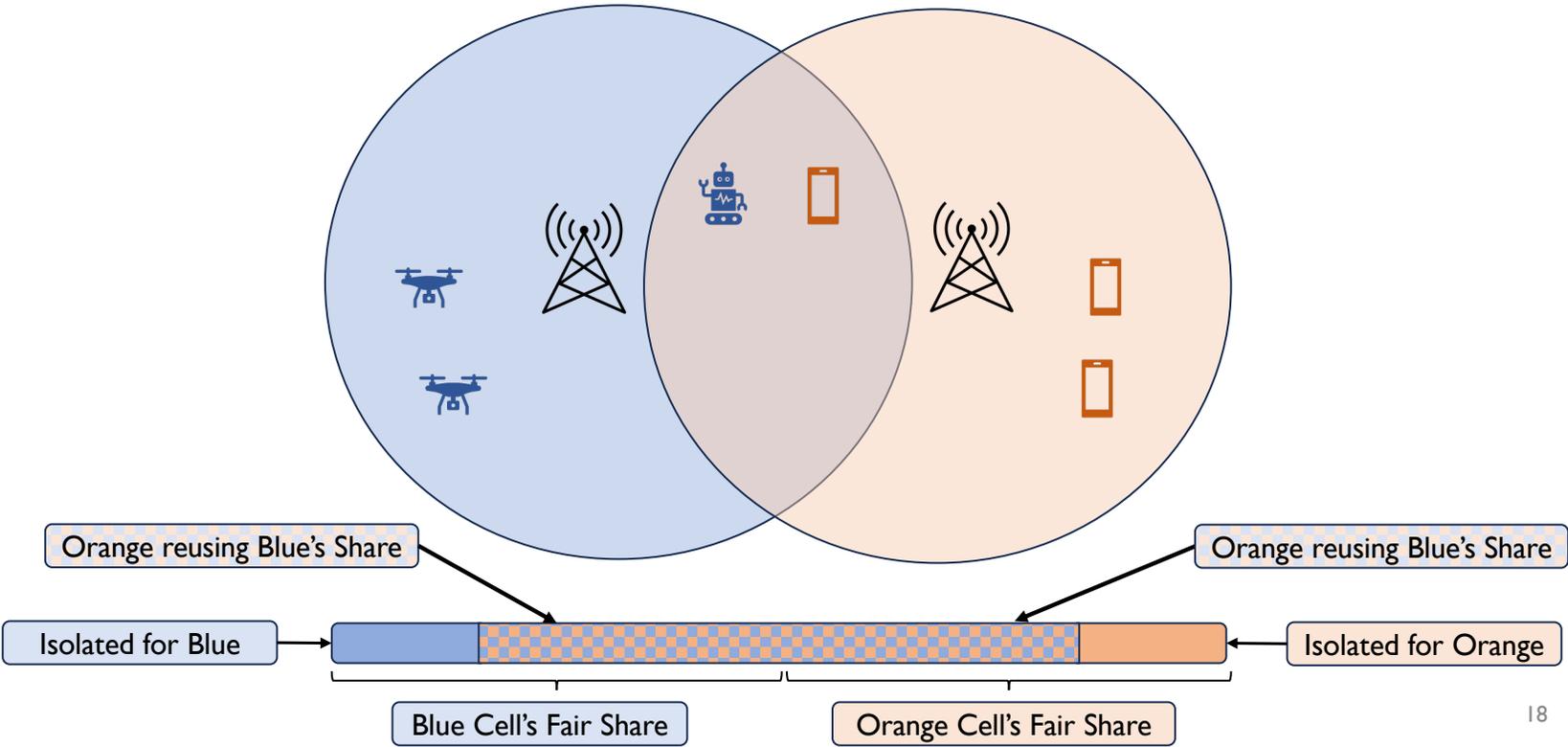
Our vision: Opportunistic Reuse



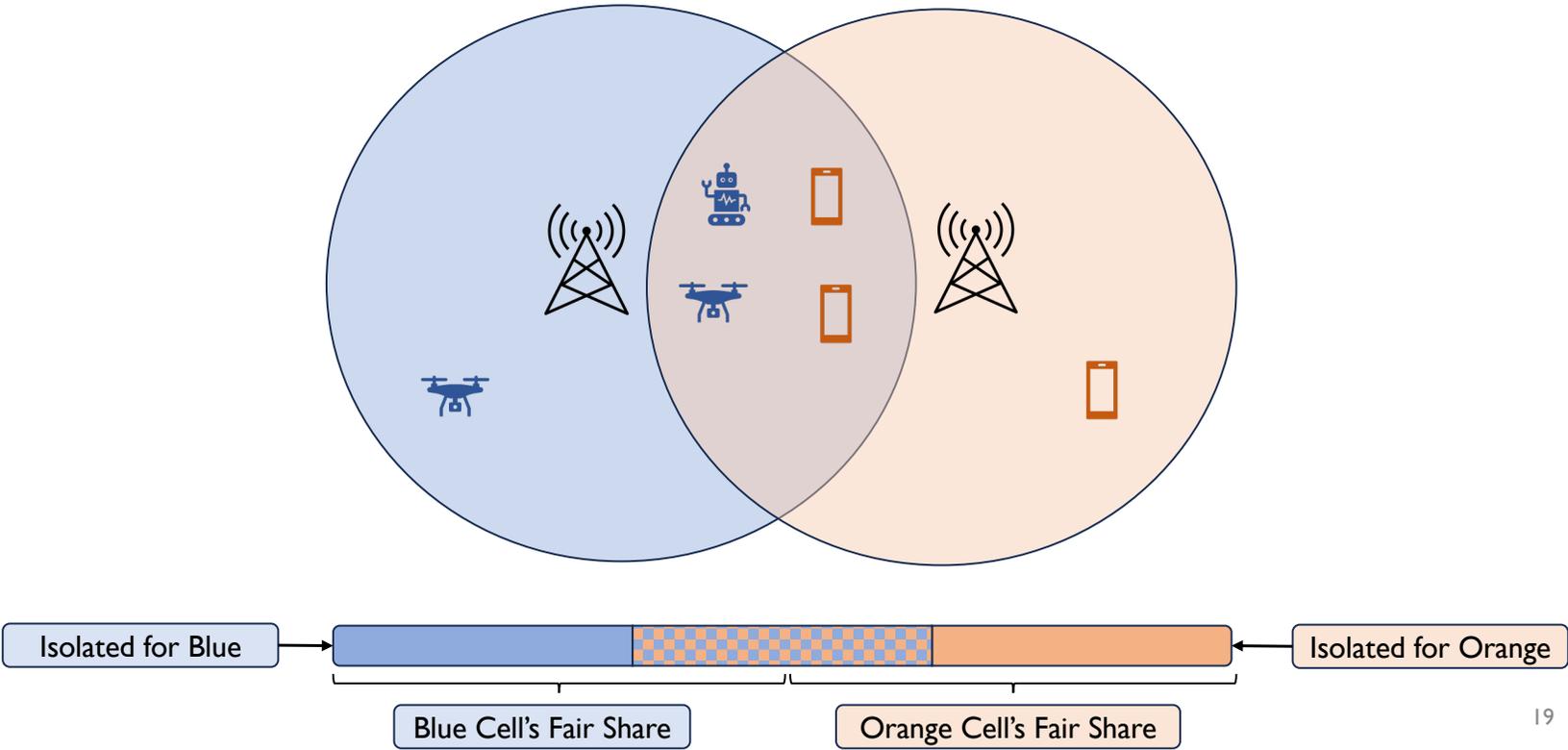
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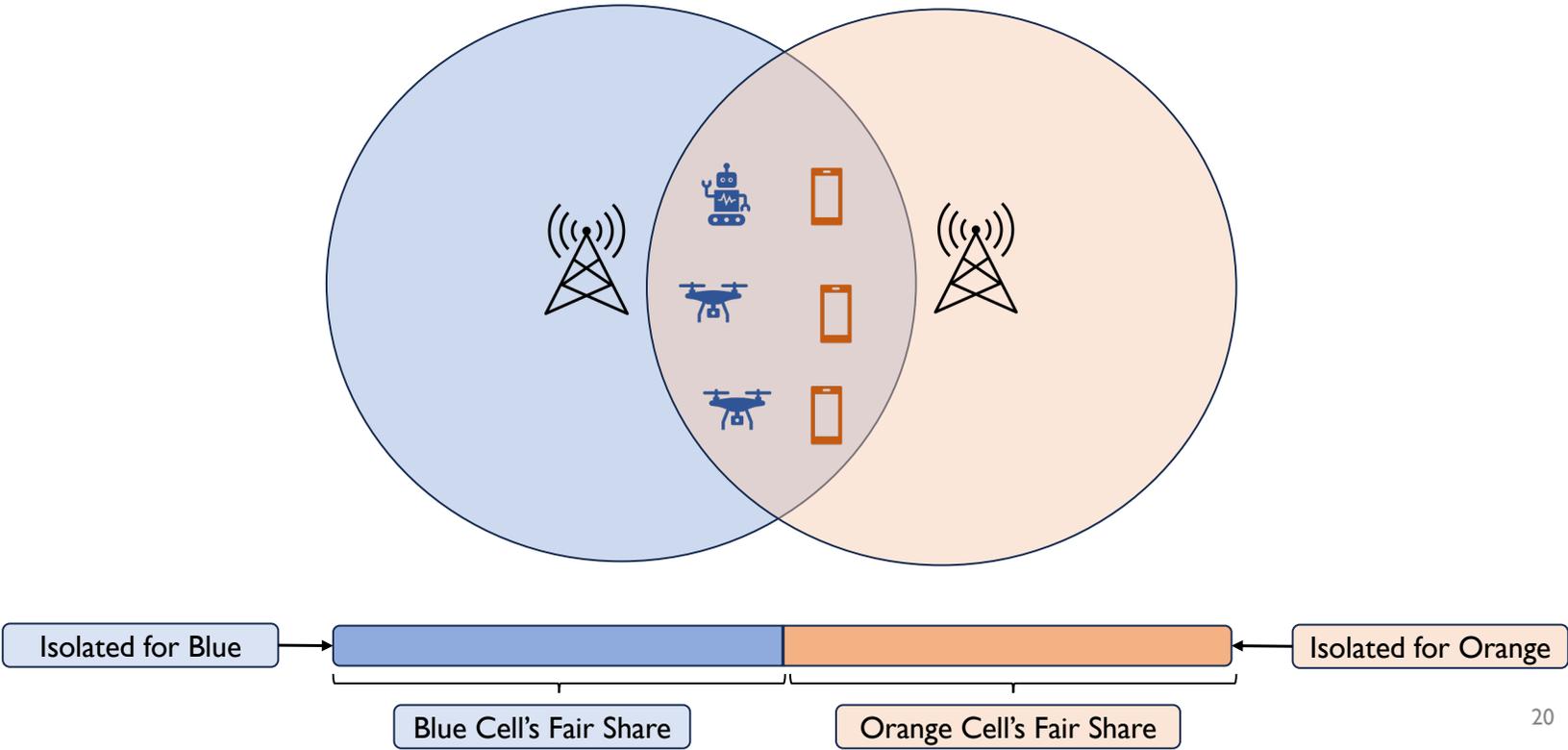
Our vision: Opportunistic Reuse



Our vision: Opportunistic Reuse



Our vision: Opportunistic Reuse



Core Idea

- Cell-based partitioning provides a starting point for fairness
- Can be inefficient
- Final partitions should be decided based on real user distribution

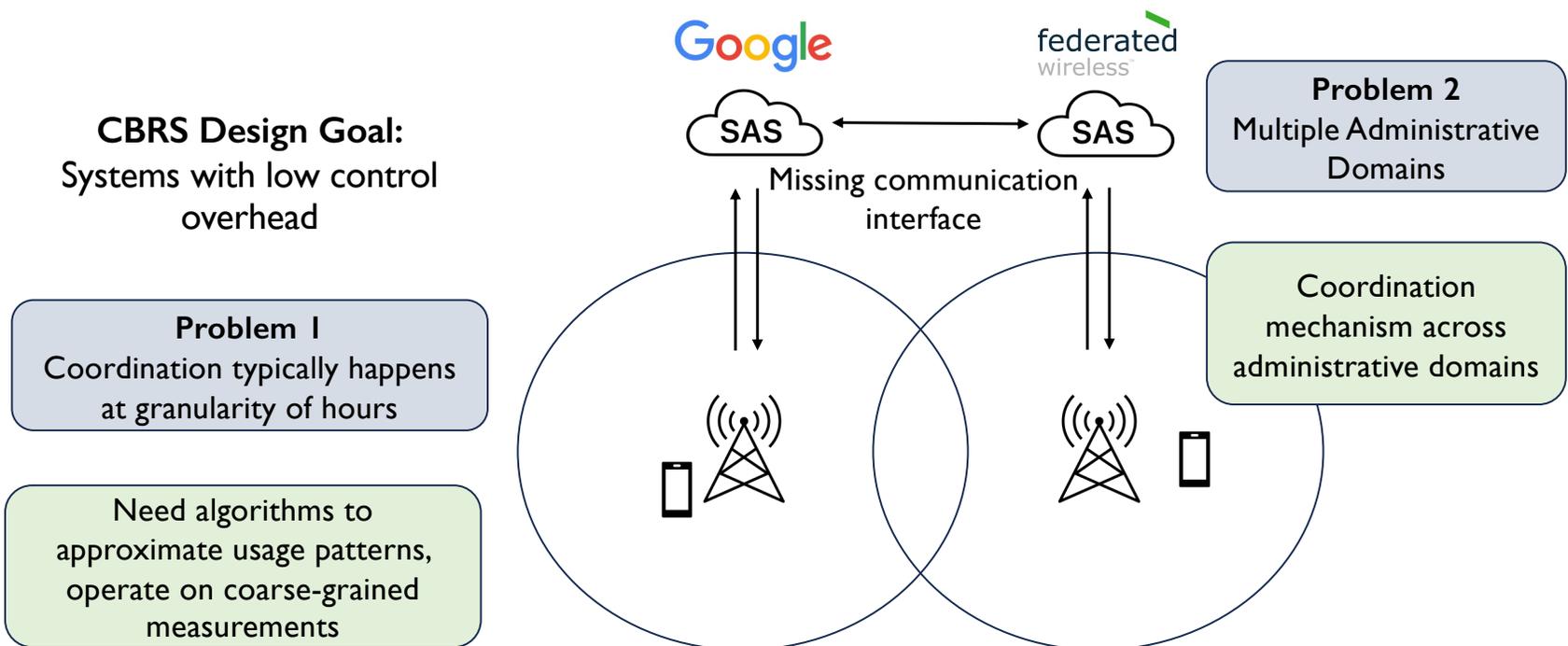
Realizing Opportunistic Reuse

- Challenges:
 - Telemetry collection
 - Incentives and preventing gamification
 - Scheduling and allocation

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Telemetry Collection



Realizing Opportunistic Reuse

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Incentives and preventing gamification

How to incentivize selfish parties to cooperate?

- Cannot rely on good will of all parties involved given commercial pressures
 - Free resource hence no notion of currency

Create incentive structures which makes cooperation the rational choice:
reciprocal sharing, reputation scores

Realizing Opportunistic Reuse

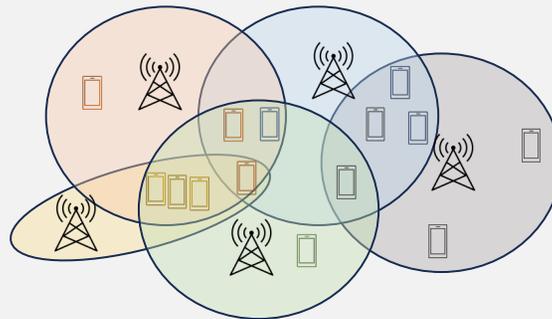
- Challenges:
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Scheduling & Allocation

Challenge 1: Accounting for Channel Quality Variations

- Not just quantity but quality of channels matters
- Allocating channels while preserving channel contiguity

Challenge 2: Handling more complex deployments



Conclusion

- **The Vacuum Threatens the Ecosystem:** The lack of built-in GAA coordination risks a "tragedy of the commons"
- **What Needs to Be Done:** We must move beyond voluntary, static spectrum partitioning
- **Why It Matters:** Enterprises will not adopt private cellular if it means gambling with unpredictable spectrum contention.