



FERMI: A Femtocell Resource Management System for Interference Mitigation in OFDMA Femtocell Networks

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Femtocells

- Small cellular base stations deployed indoors.
 - ✓ Use existing cable backhaul and cellular access technology
 - ✓ Short range, high throughput
 - ✓ Clients save power on the uplink
- Interference is inevitable among collocated femtocells.
 - ✓ different problem than interference in WiFi
 - **What can we do?**

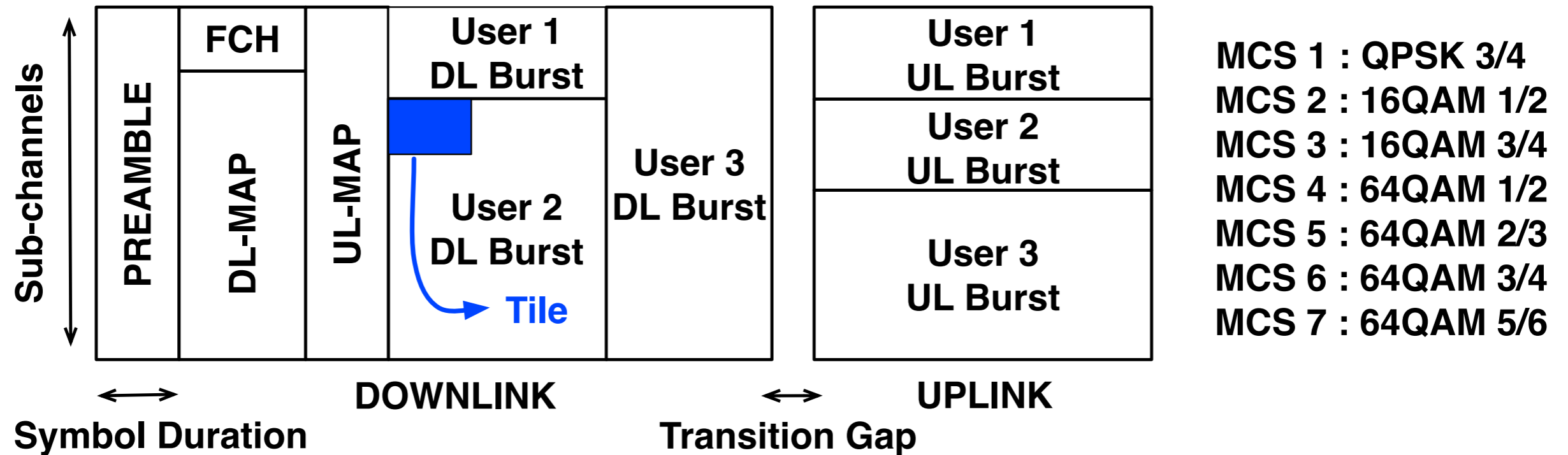
Contributions

- **FERMI** - mitigates interference among OFDMA femtocells deployed in an enterprise.
 - ✓ Centralized algorithms to assign orthogonal frequencies to interfering femtocells.
 - ✓ Flexible frame format that supports heterogeneous client requirements for better spatial reuse.
- First solution implemented on an actual OFDMA femtocell testbed with **off-the-shelf** clients!

Roadmap

- WiMAX preliminaries
- Interference among femtocells
 - ✓ Can we leverage existing WiFi solutions?
 - ✓ If not, how should the solution look like?
- Algorithms for interference management
- Evaluation

WiMAX Preliminaries

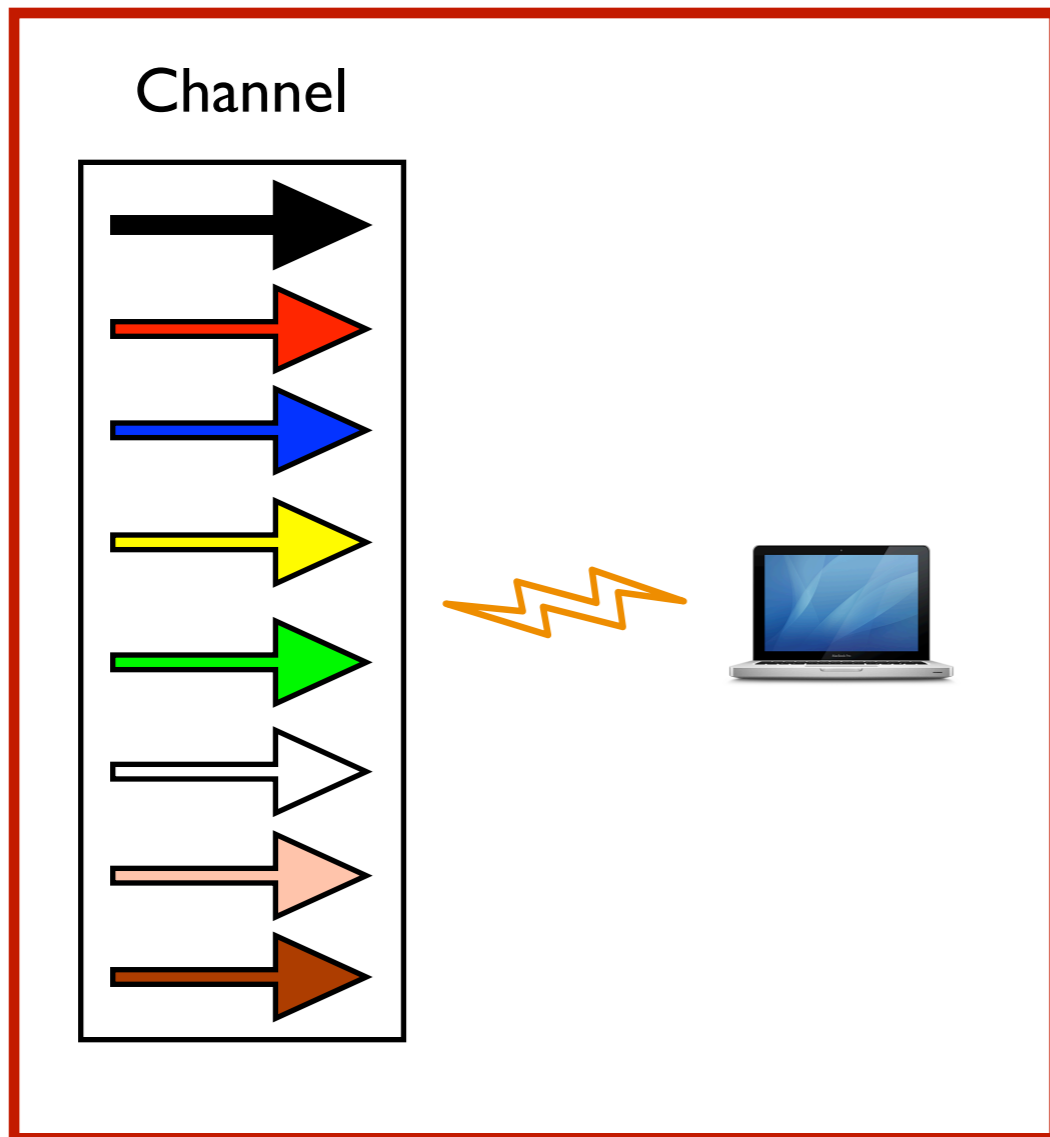


- Multiple users scheduled in the same frame.
- BS schedules tiles for both downlink and uplink.
- Synchronous MAC (no carrier sensing).
 - ✓ frames sent every 5 ms (1 ms for LTE)

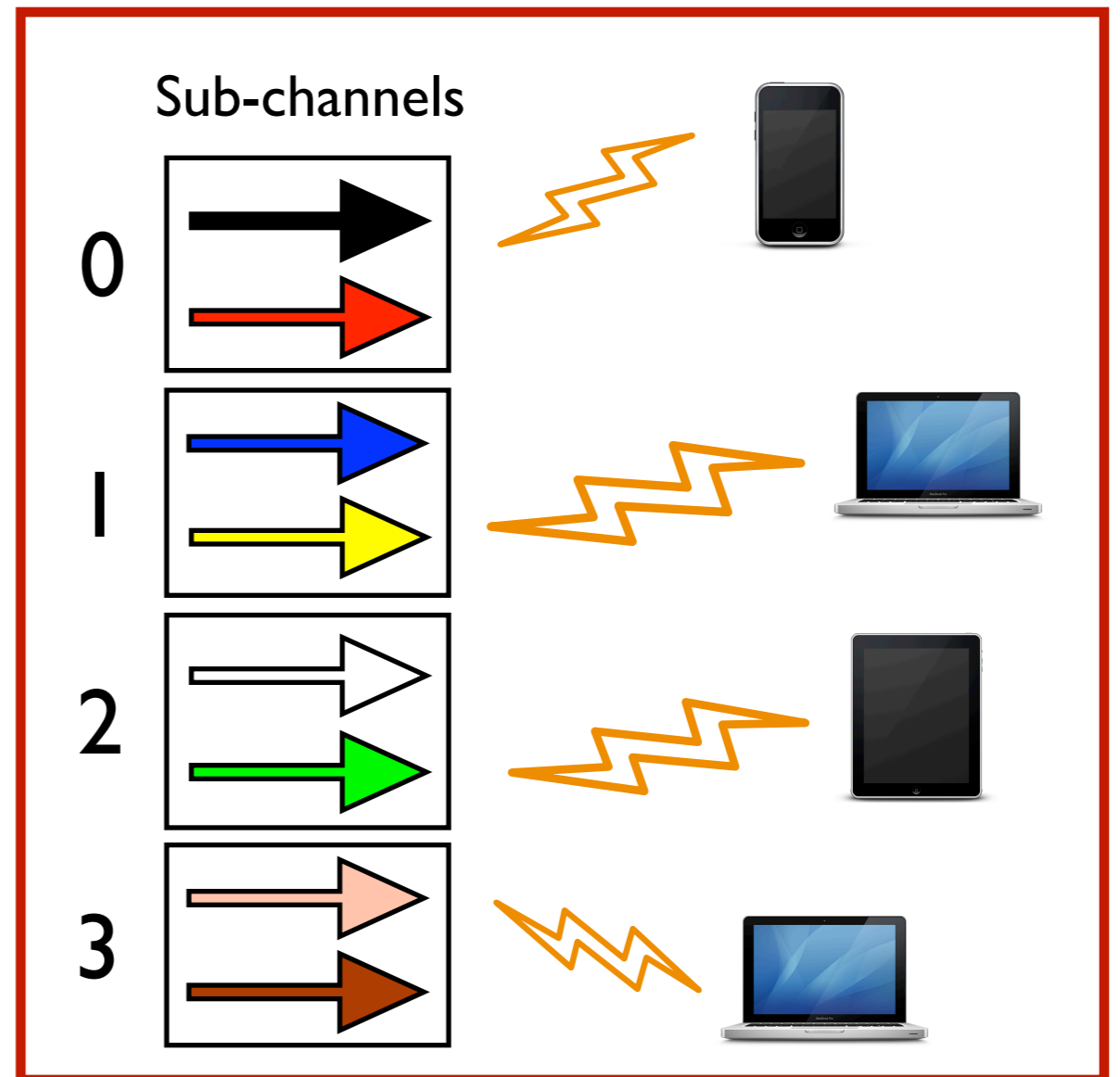
OFDMA vs OFDM

- WiMAX uses OFDMA technology at the PHY.

WiFi (OFDM)



WiMAX (OFDMA)

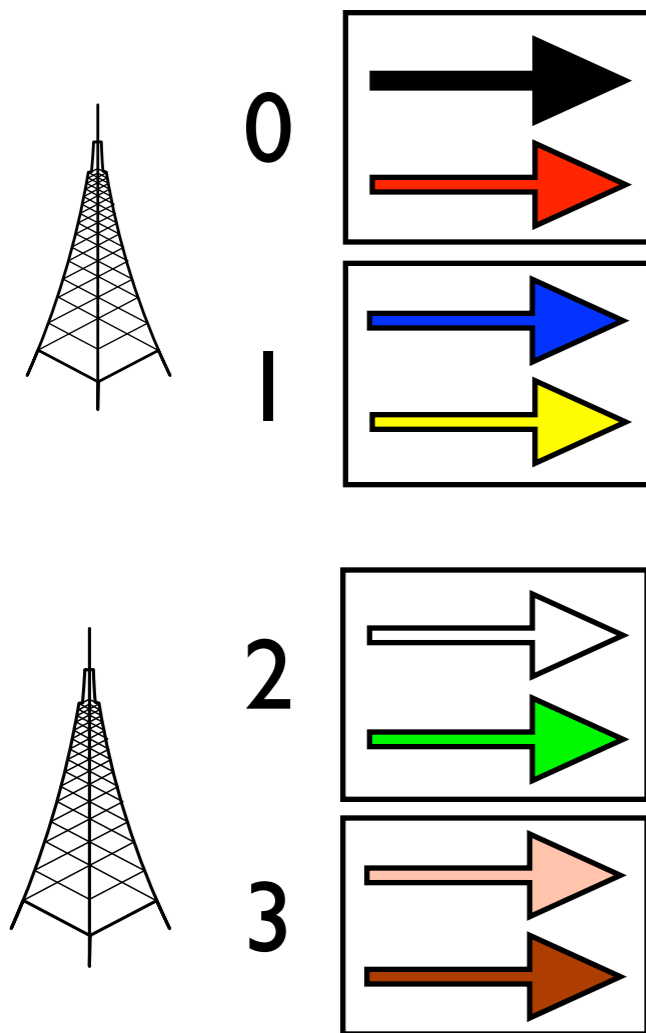


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Existing Solutions for WiFi

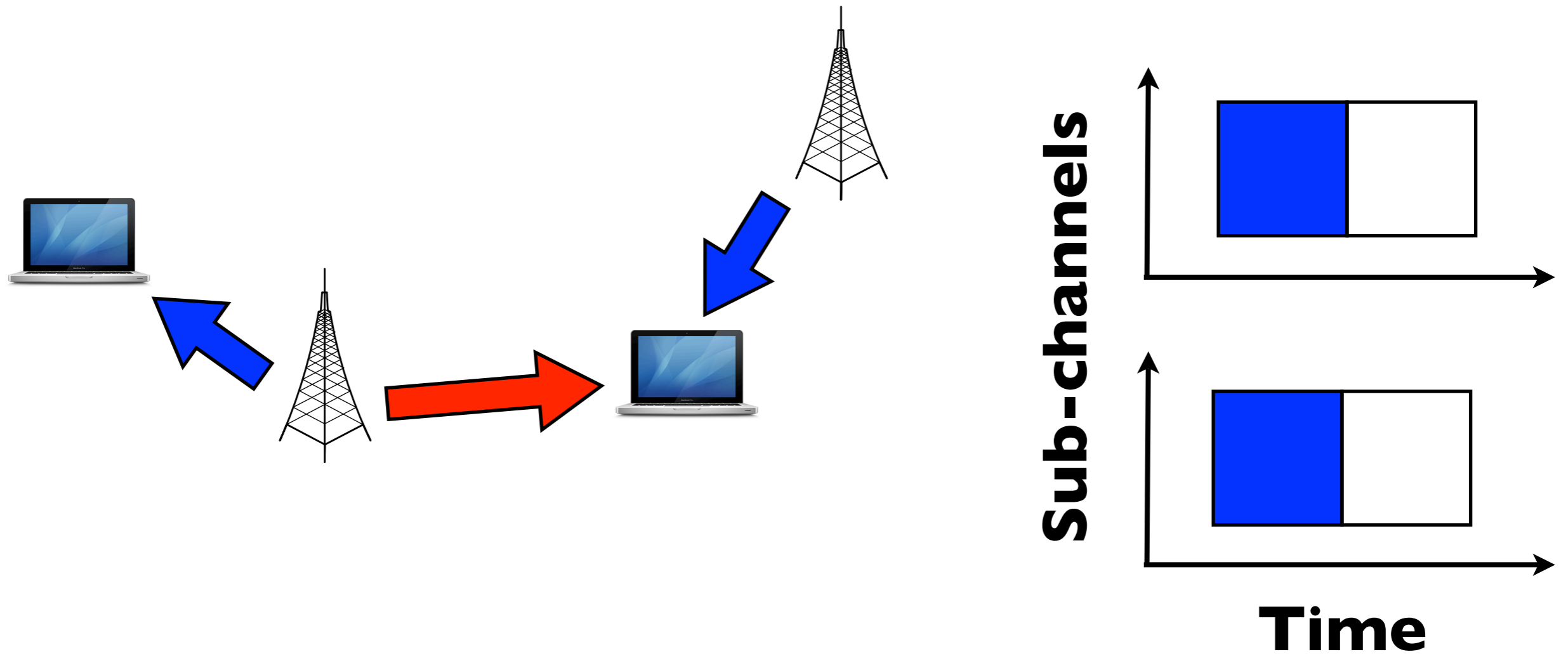
- Tune interfering WiFi APs to orthogonal channels.



Equivalent Solution for Femtocells

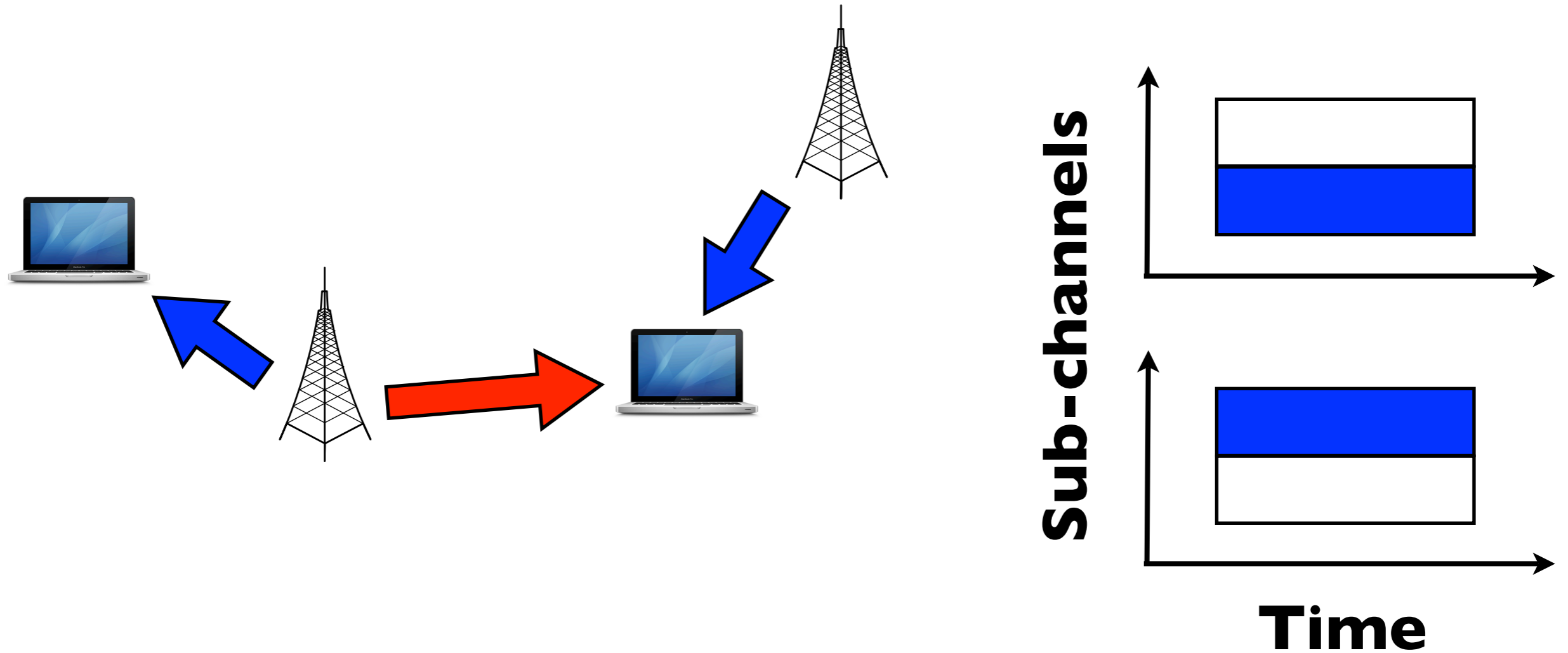
- Licensed spectrum
- Orthogonal **sub-channels** to interfering femtocells.
- Under-utilization for clients who are not subject to interference.
- Multiple clients should coexist.

How do we define interference?



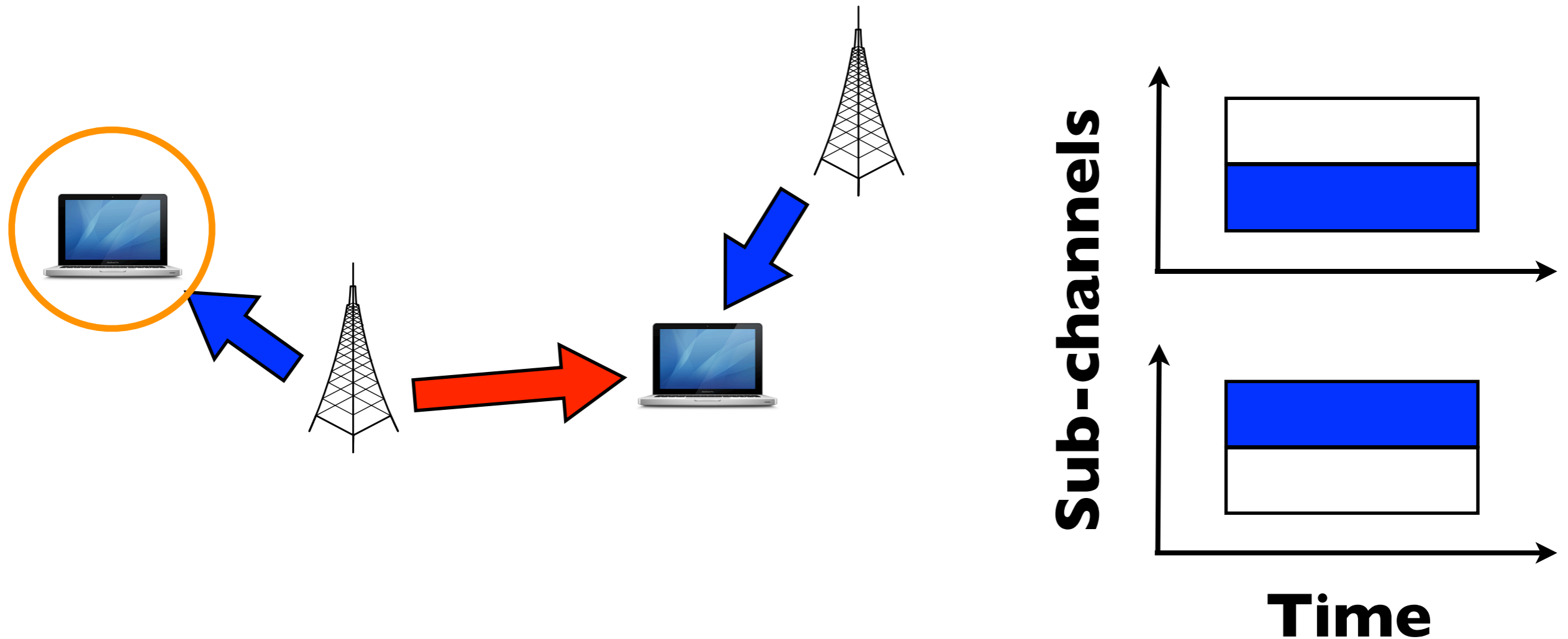
- Degradation of decoding at the clients (**need isolation**).

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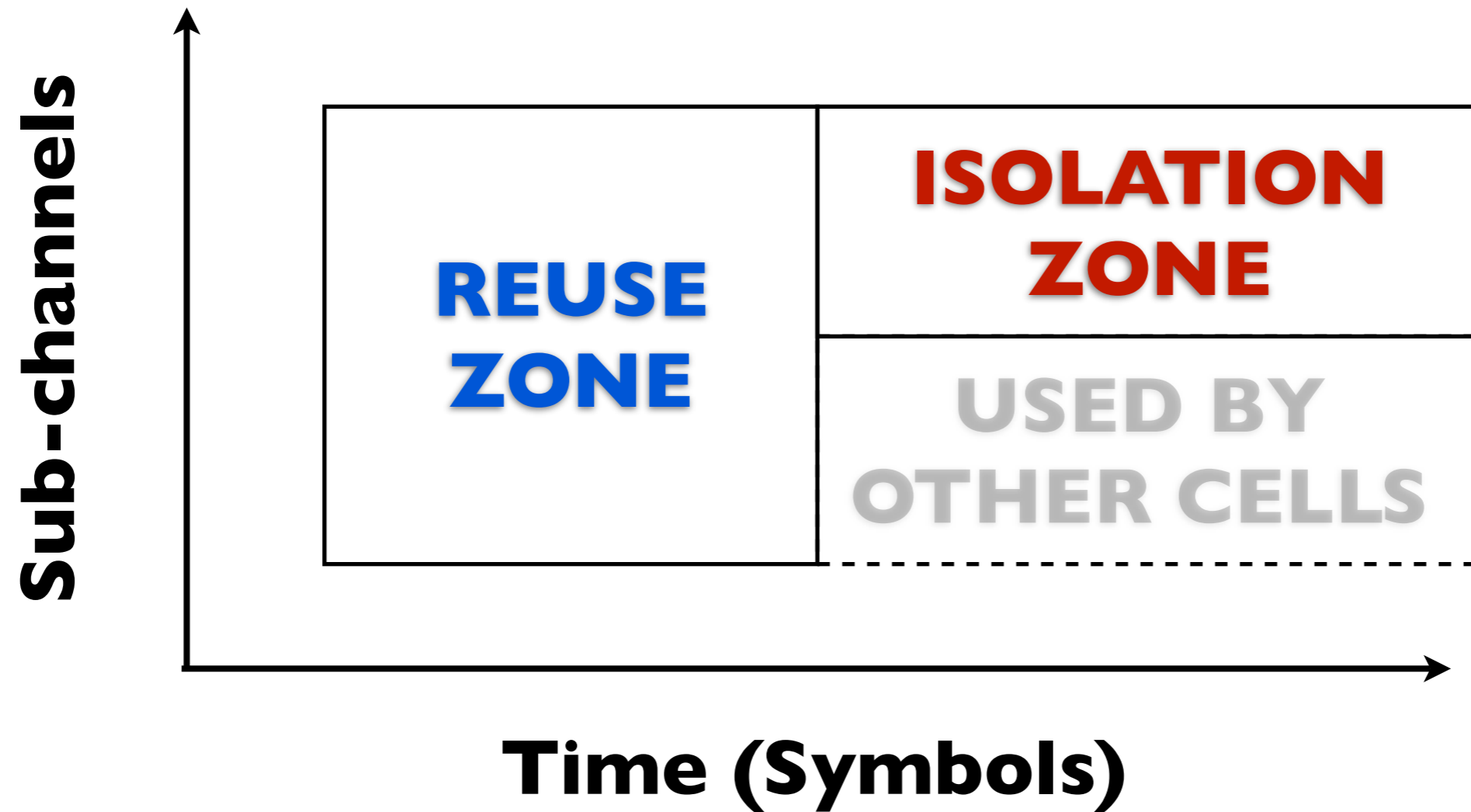
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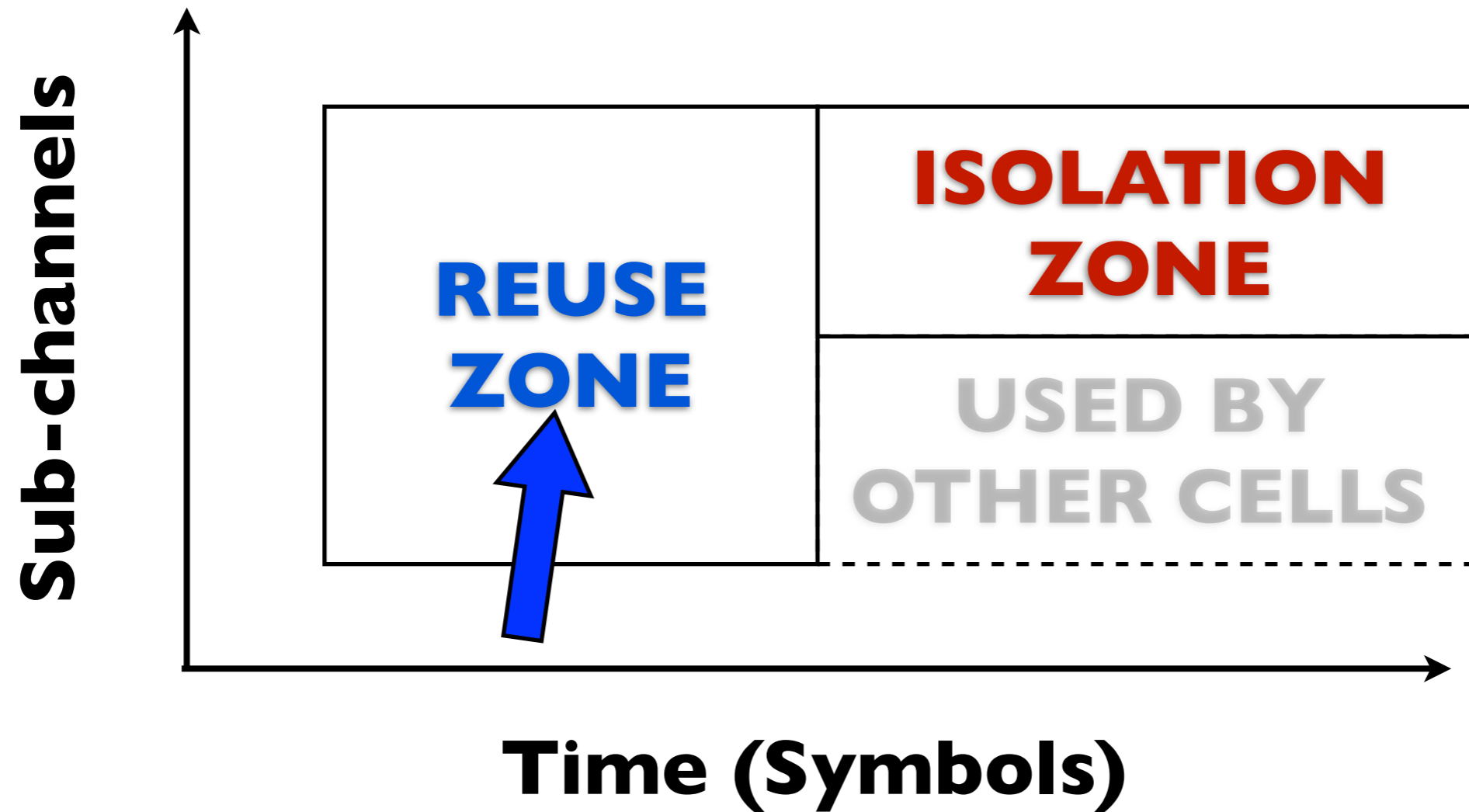


- Degradation of decoding at the clients (**need isolation**).
- **GOAL:** Intelligent resource management to improve network utilization (taking into account both clients.)

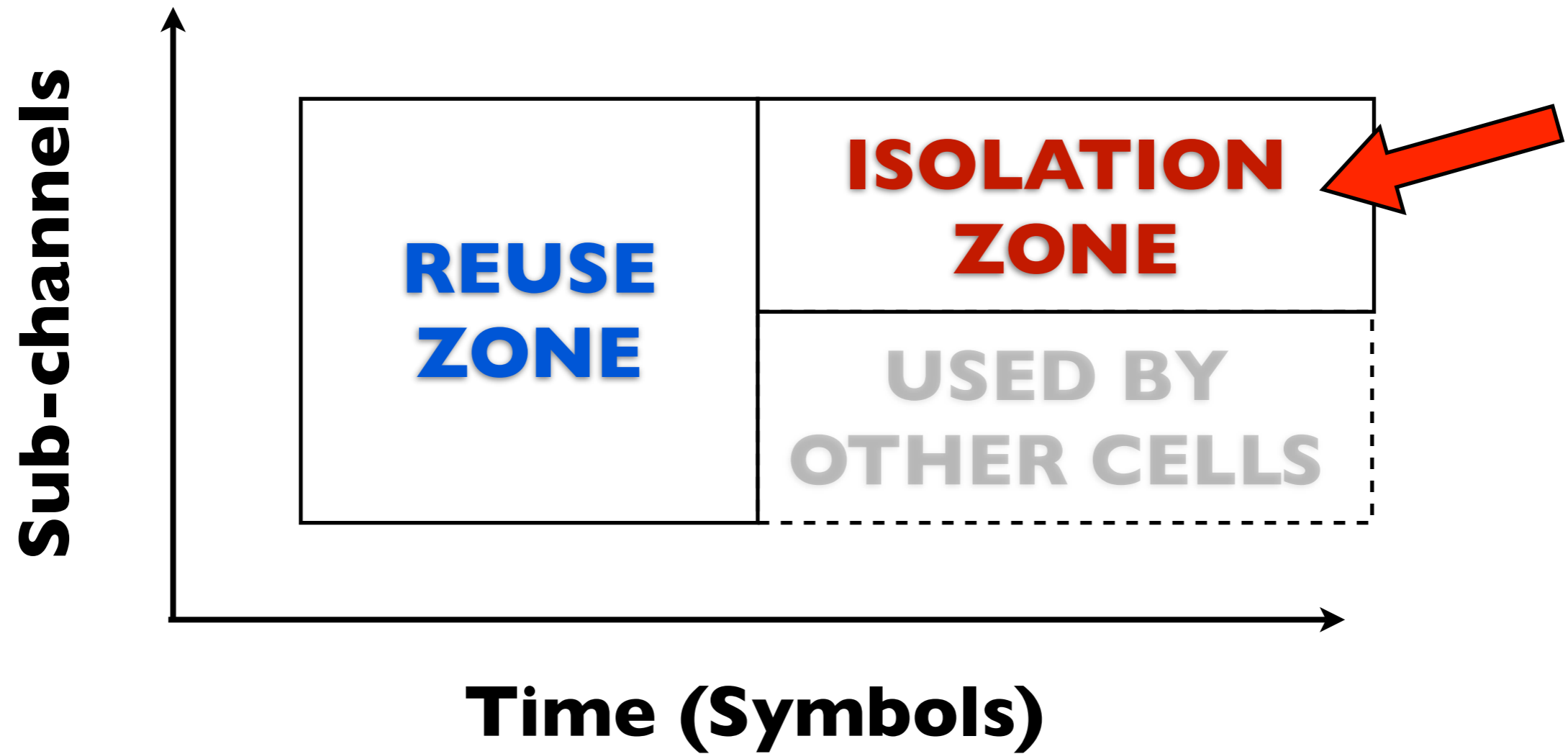
What should the solution look like?



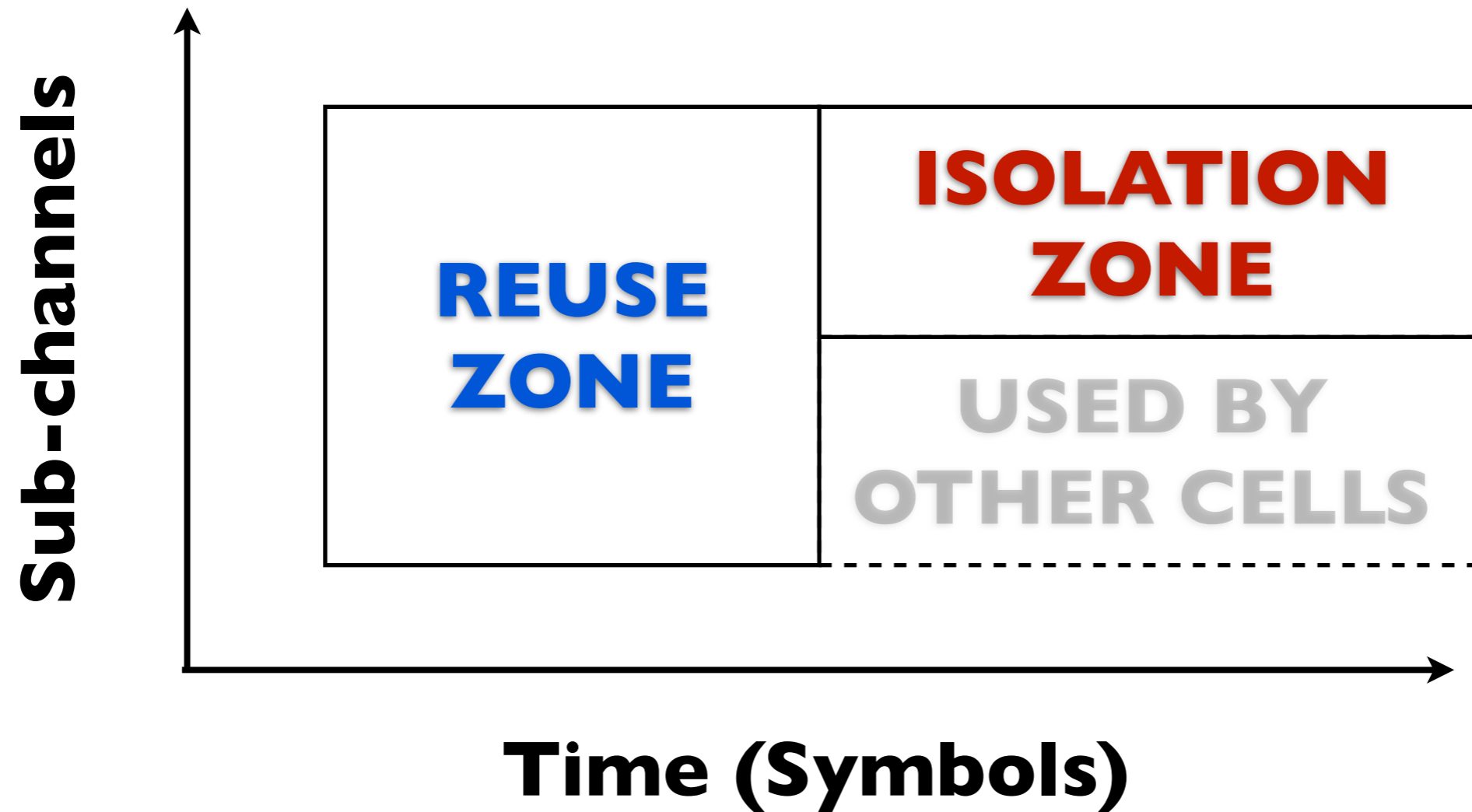
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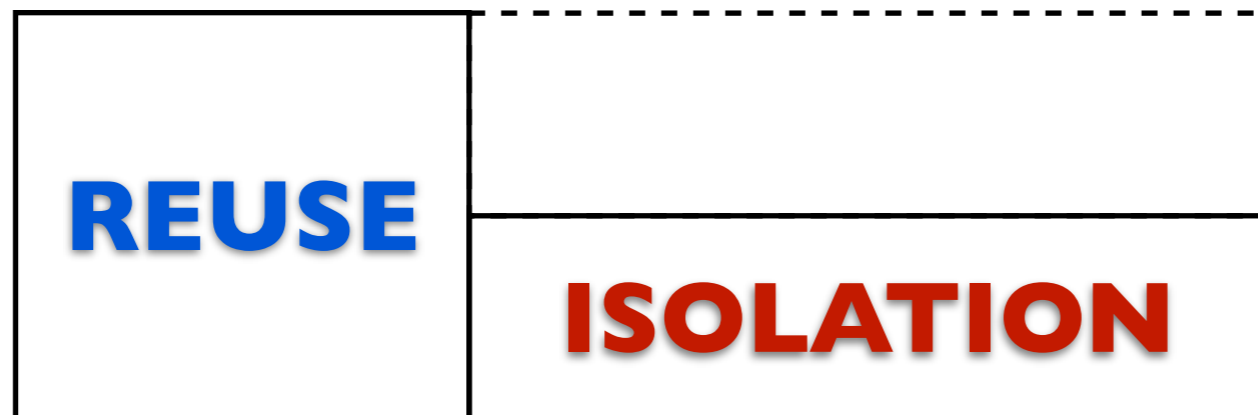
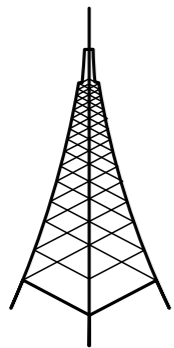
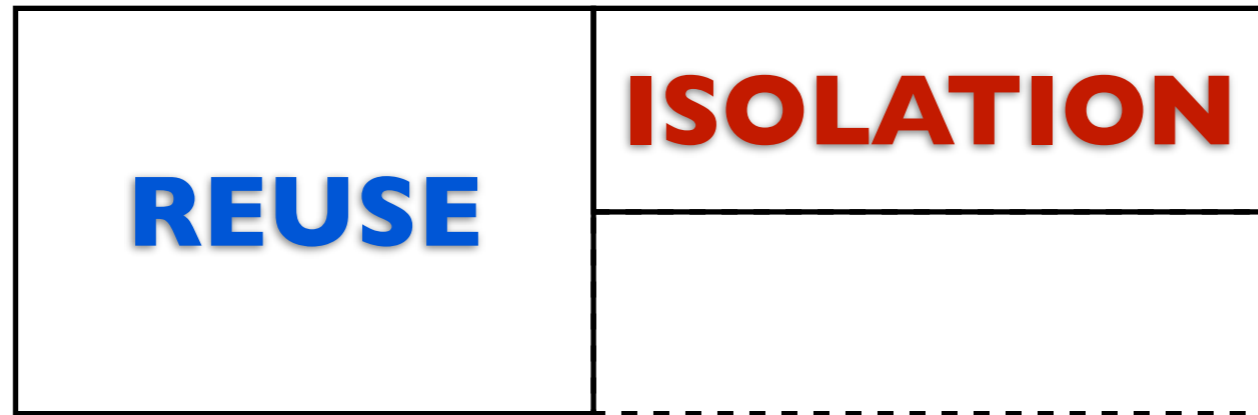
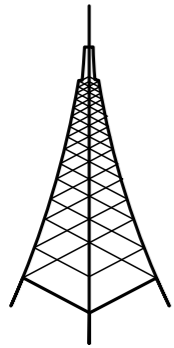


✓ Load-based adjustment of zones.

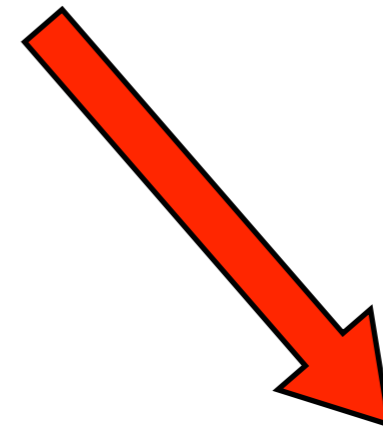
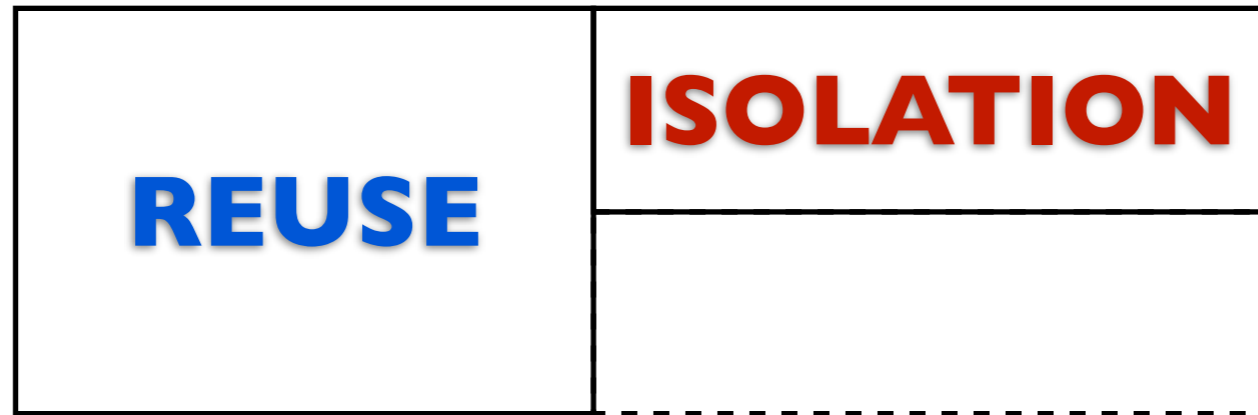
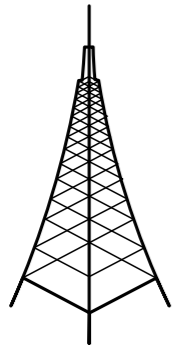
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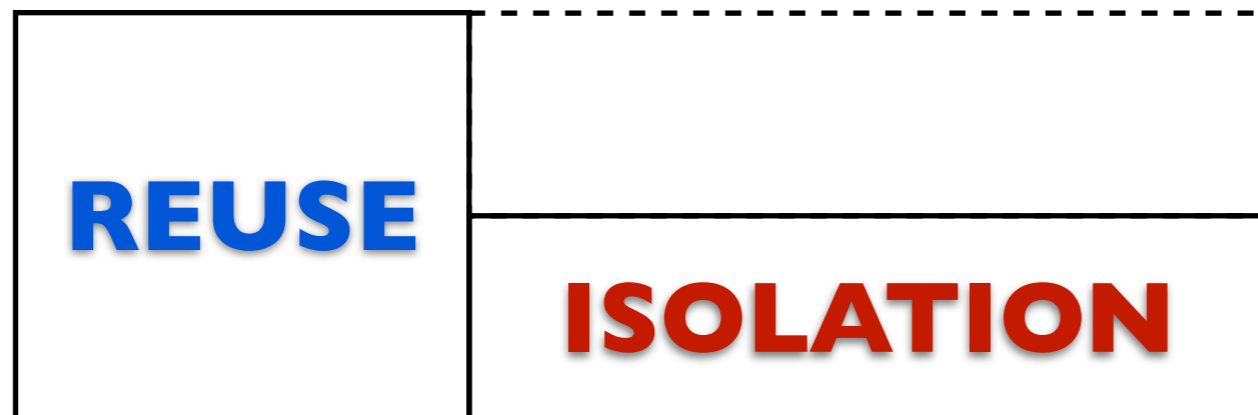
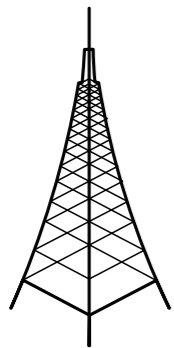
Algorithms (Overview)



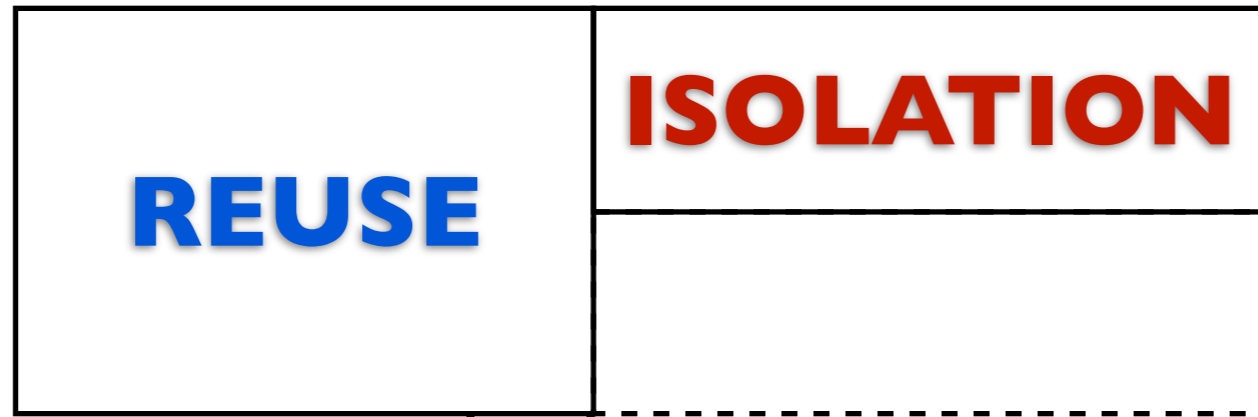
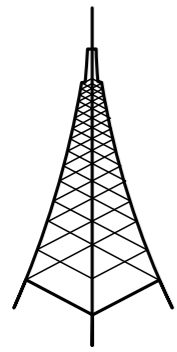
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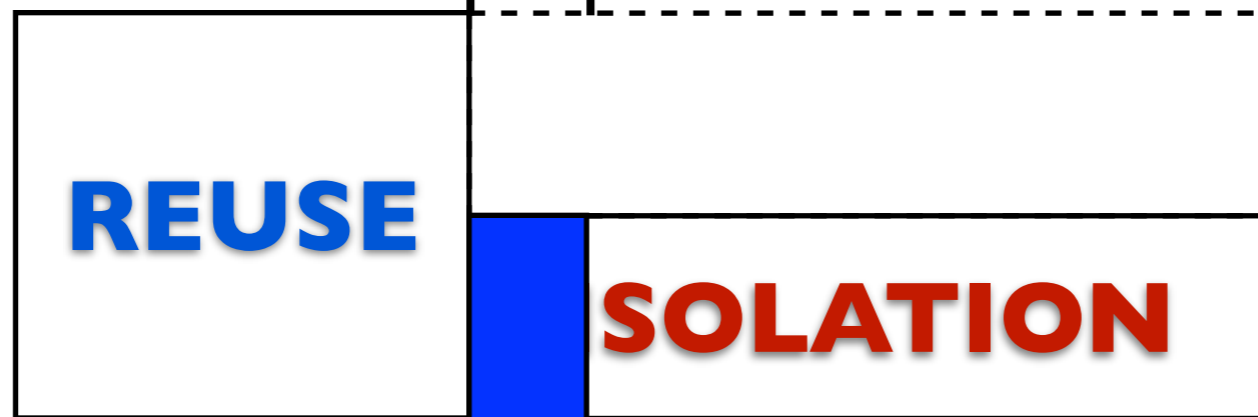
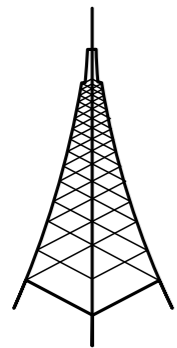
allocate &
assign (coloring)



Algorithms (Overview)



 determine common reuse zone size

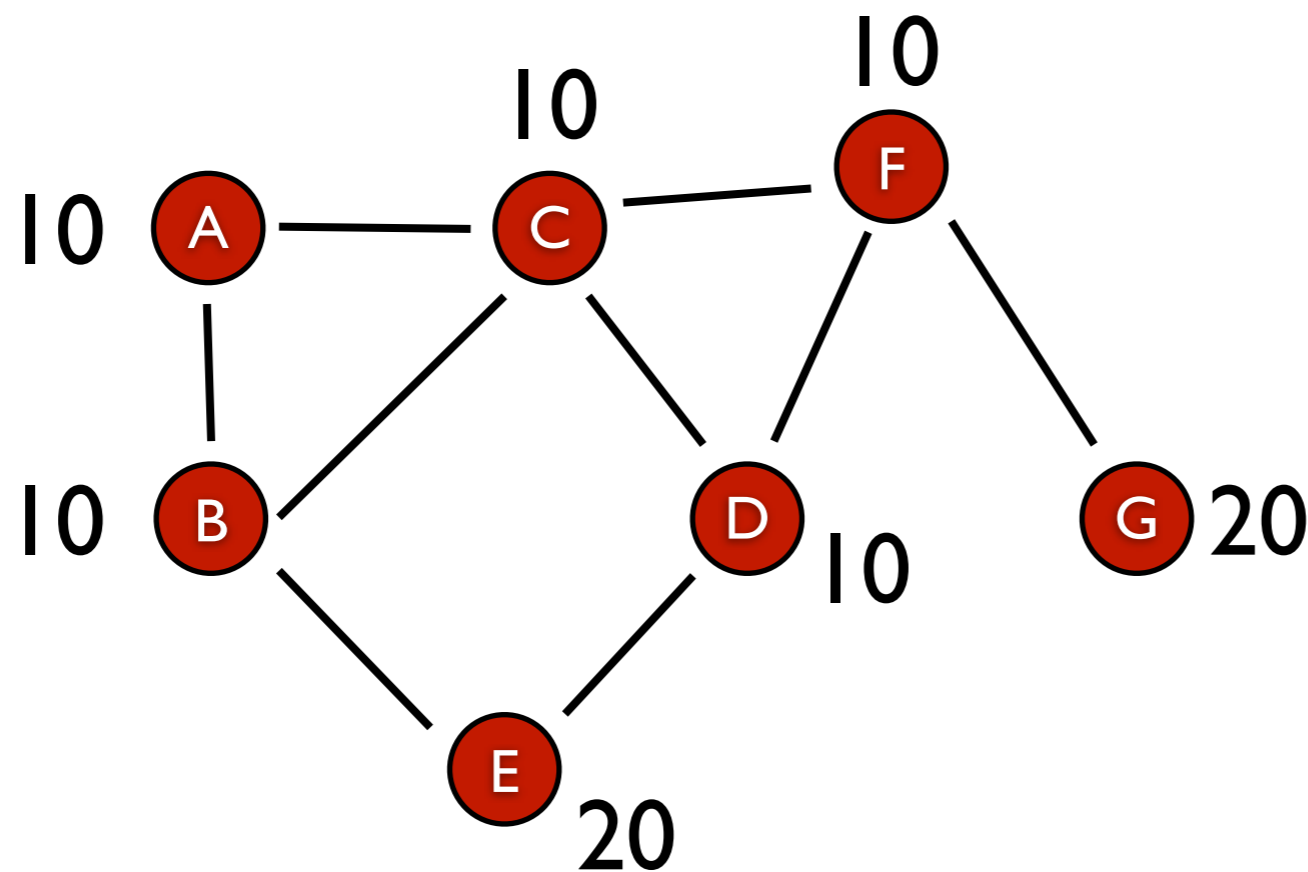


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- Weighted max-min fair allocation
- Need to list all **maximal** cliques: NP-hard

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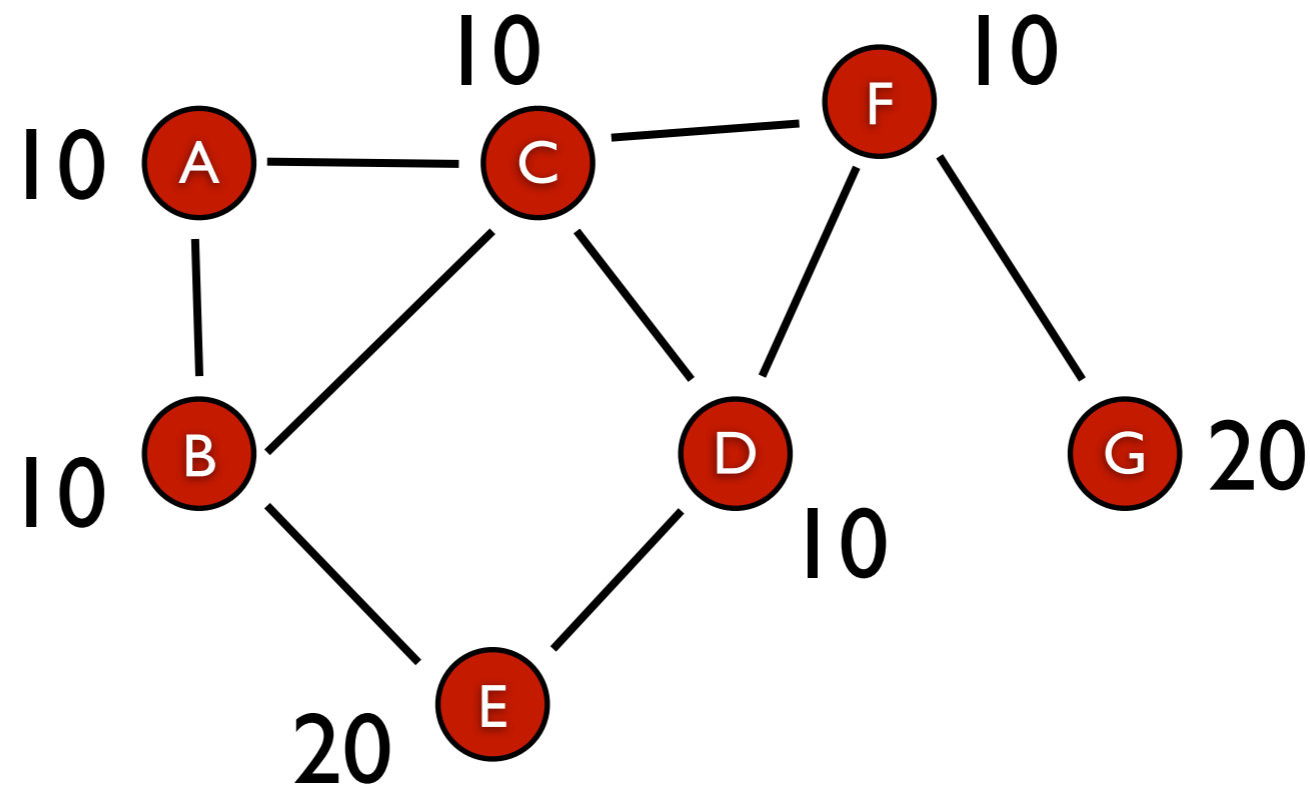
30 sub-channels
with equal load

Sub-channel Allocation

- Chordal graphs: no cycles of more than 3.
- Triangulation: transform general graph G to a chordal graph G'
- All maximal cliques can be listed in polynomial time!

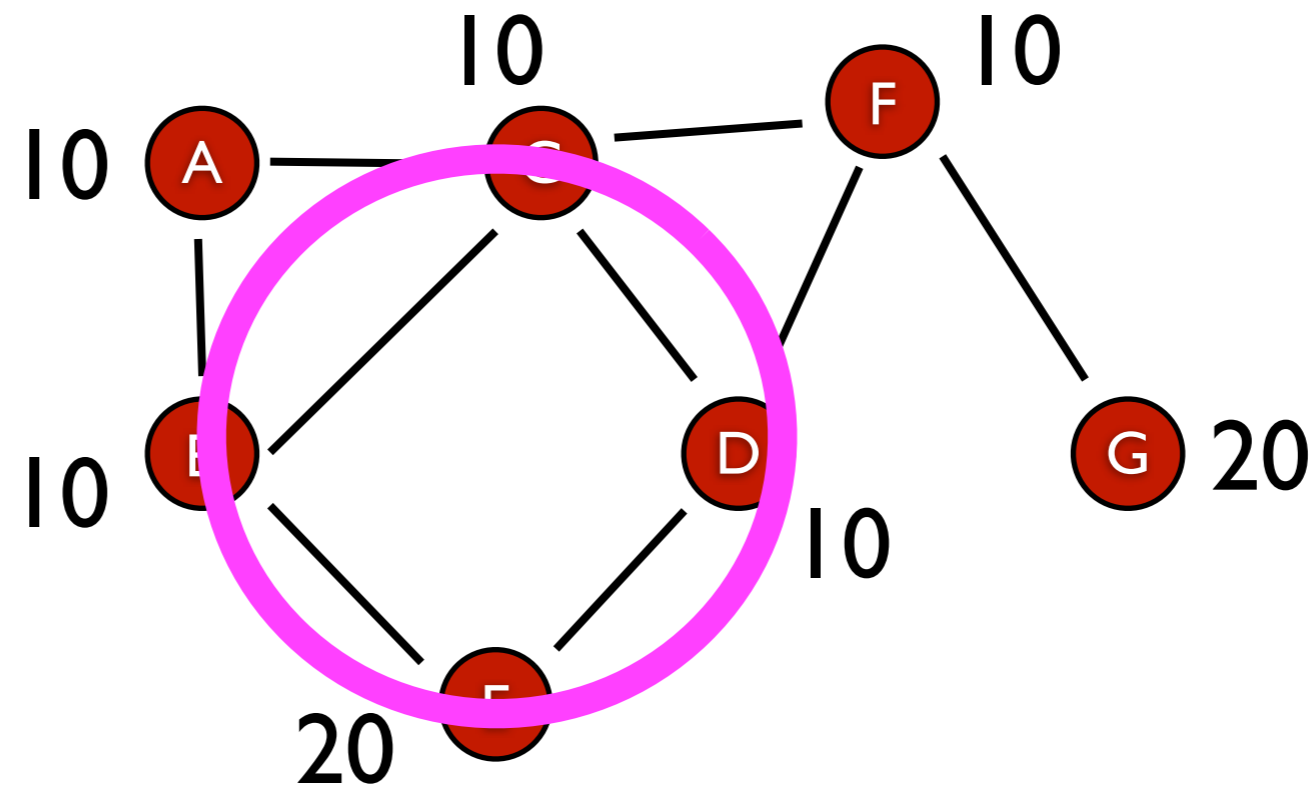
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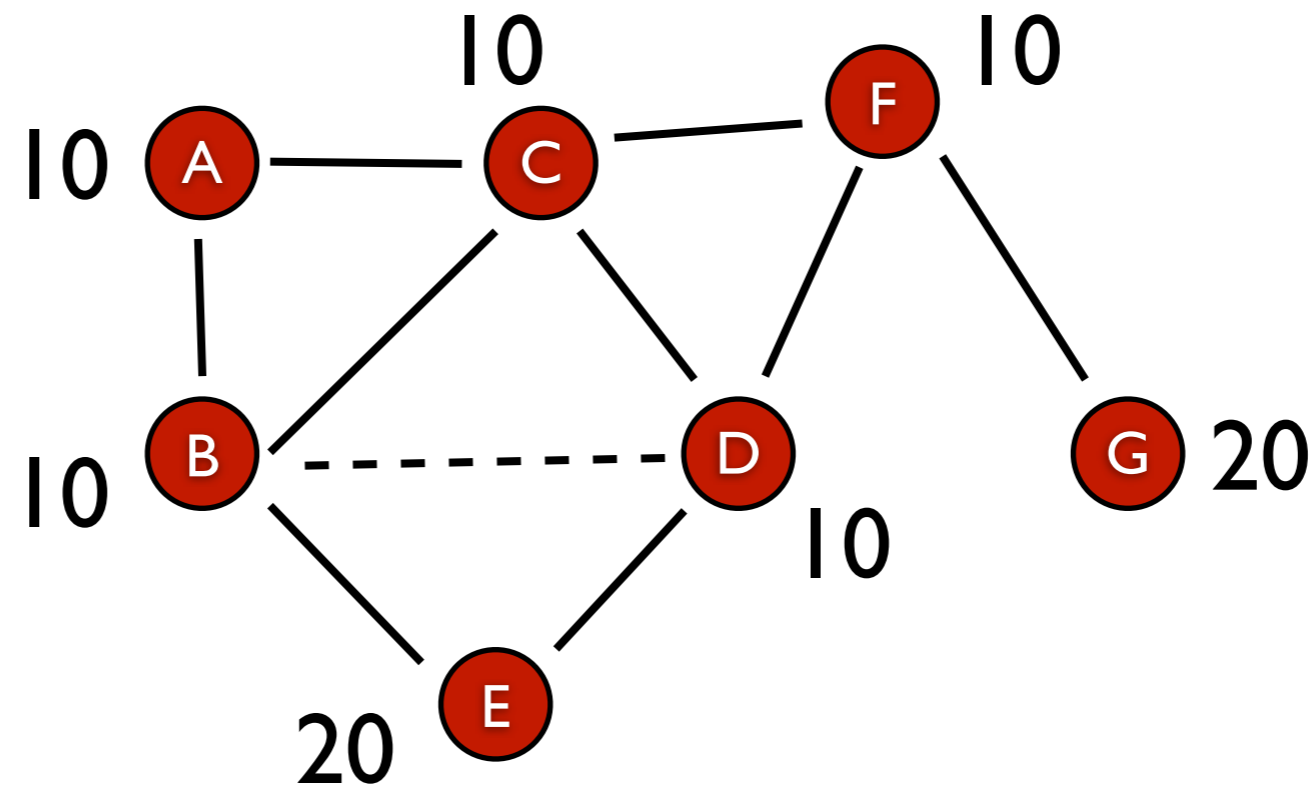
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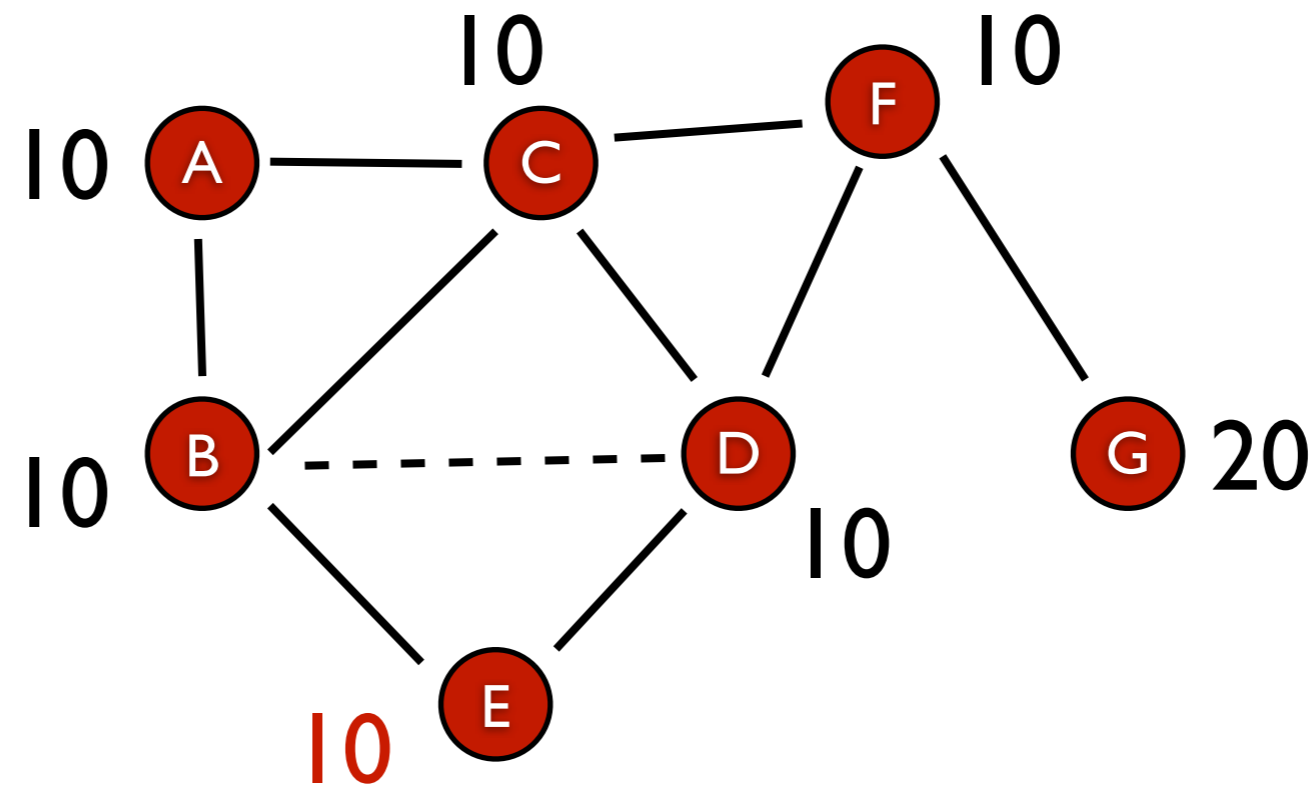
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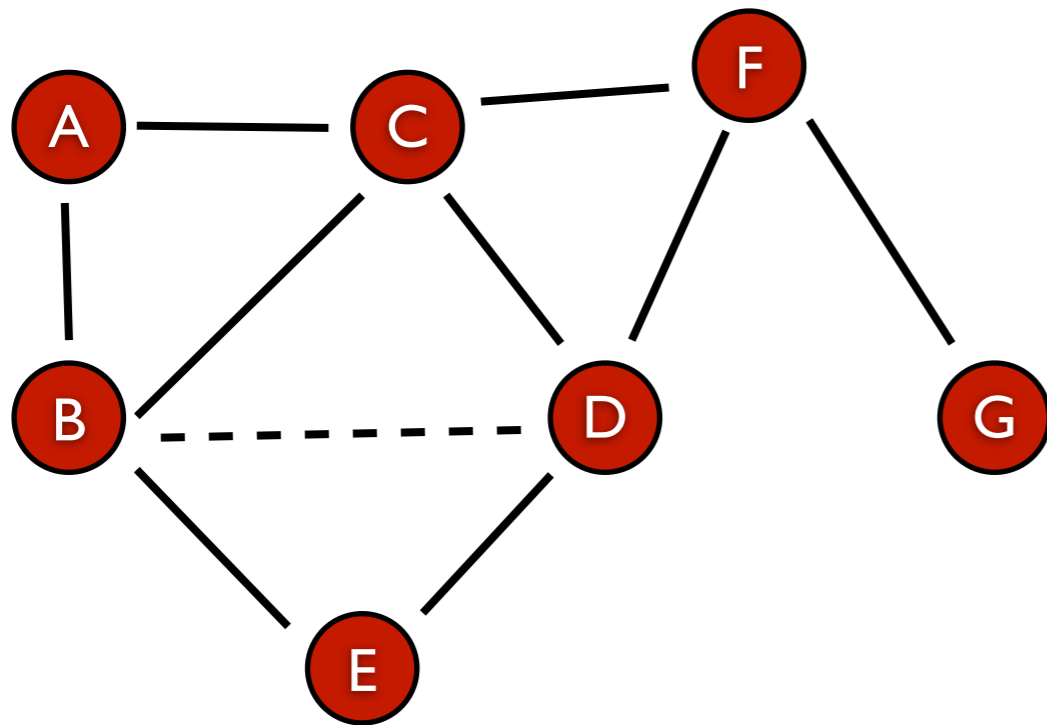
Sub-channel Assignment

- Coloring with multiple colors (sub-channels).
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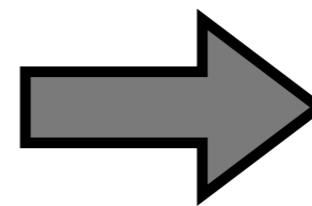
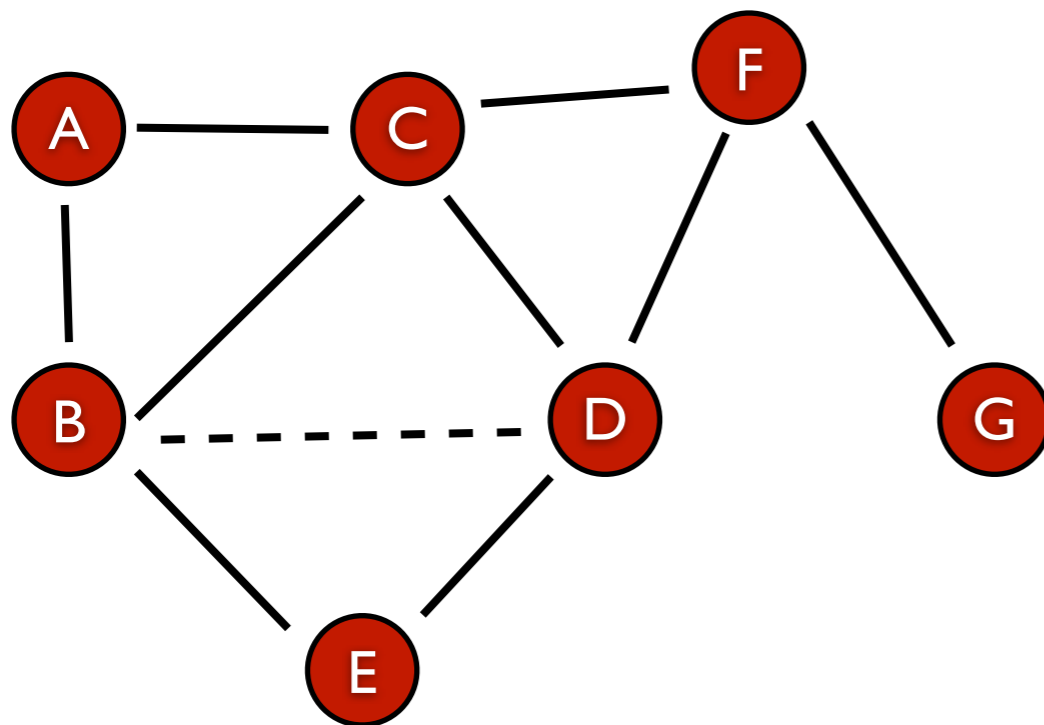
Chordal graph



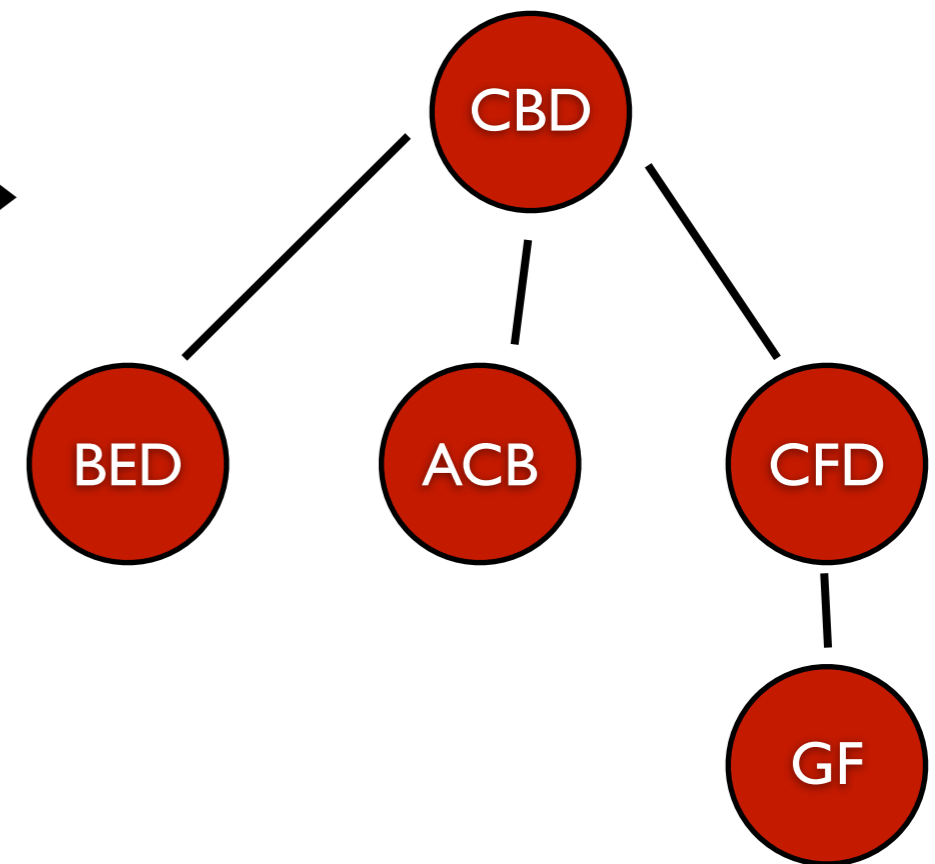
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Chordal graph



Clique tree

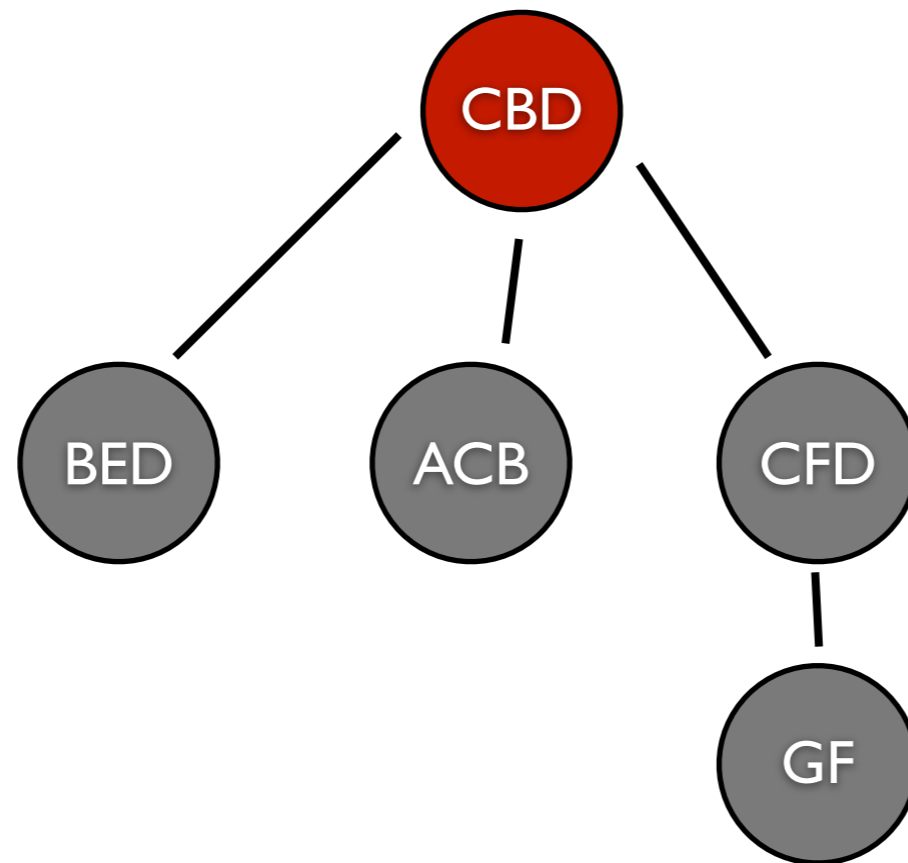


Sub-channel Assignment

- Color each level starting from the root.

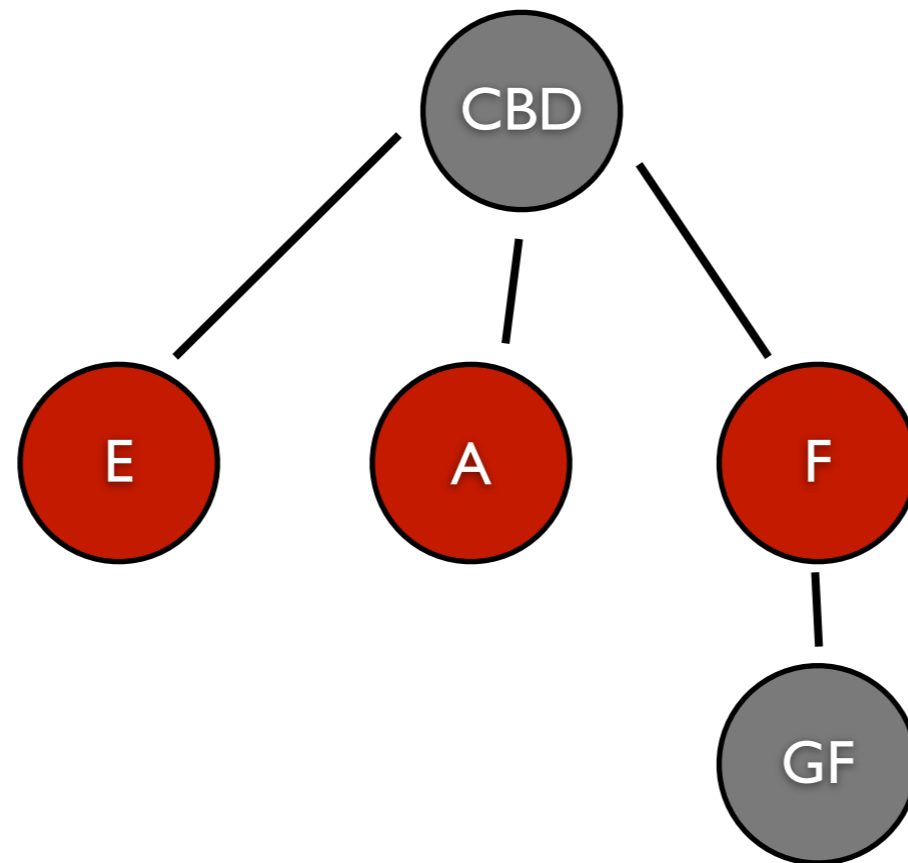
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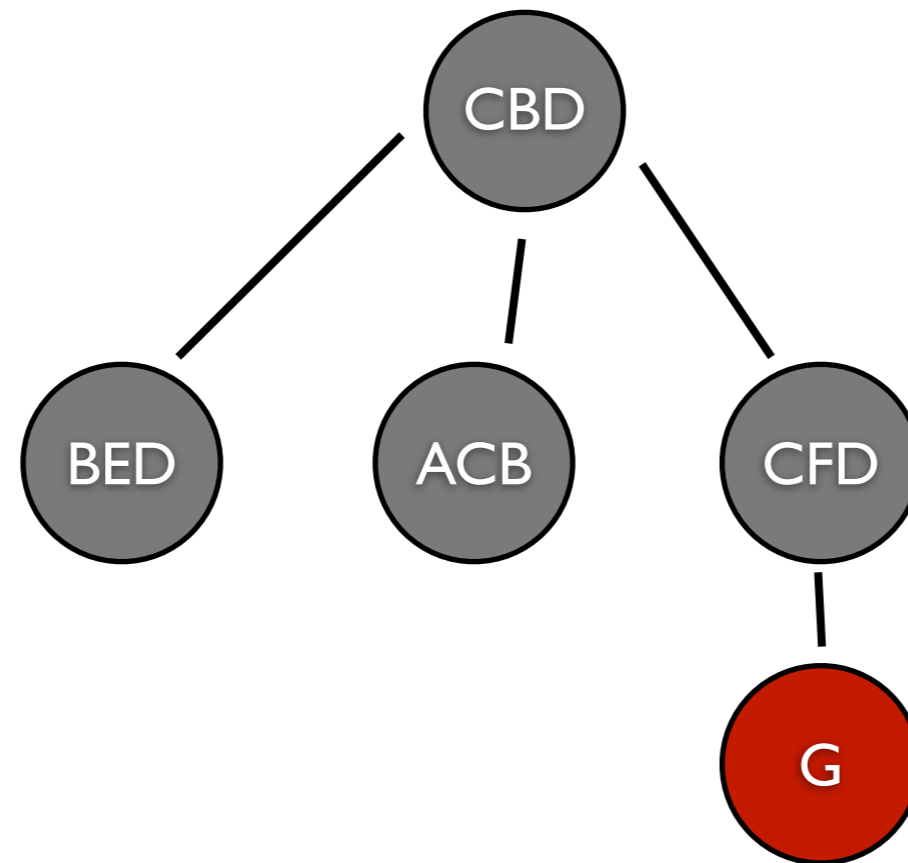
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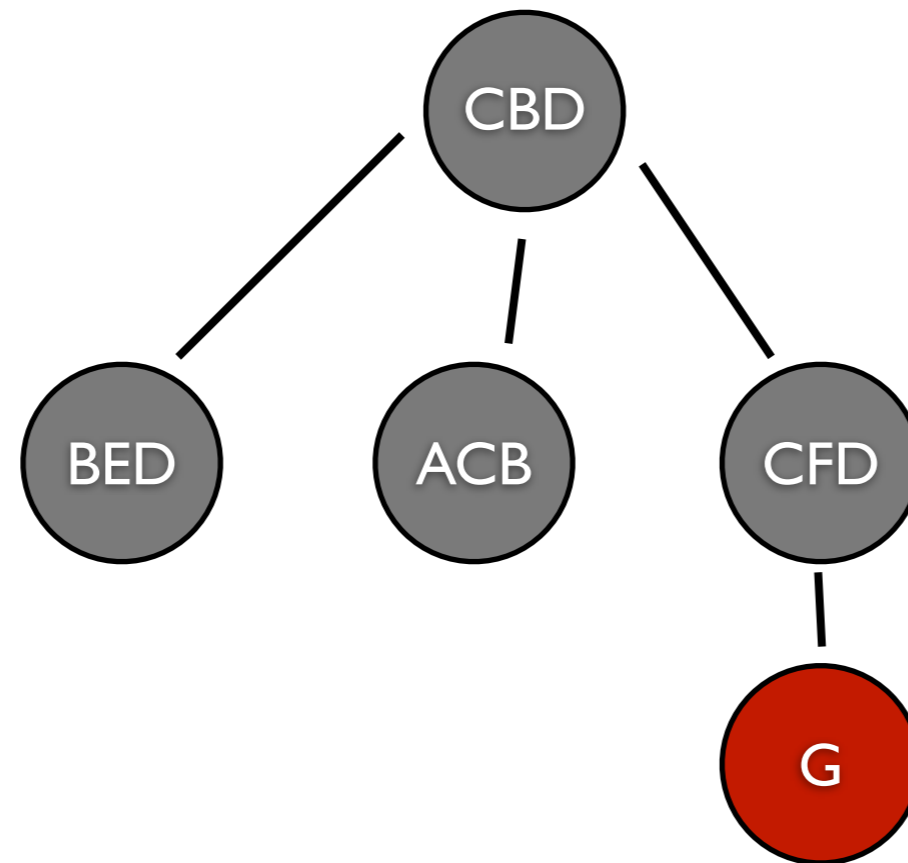
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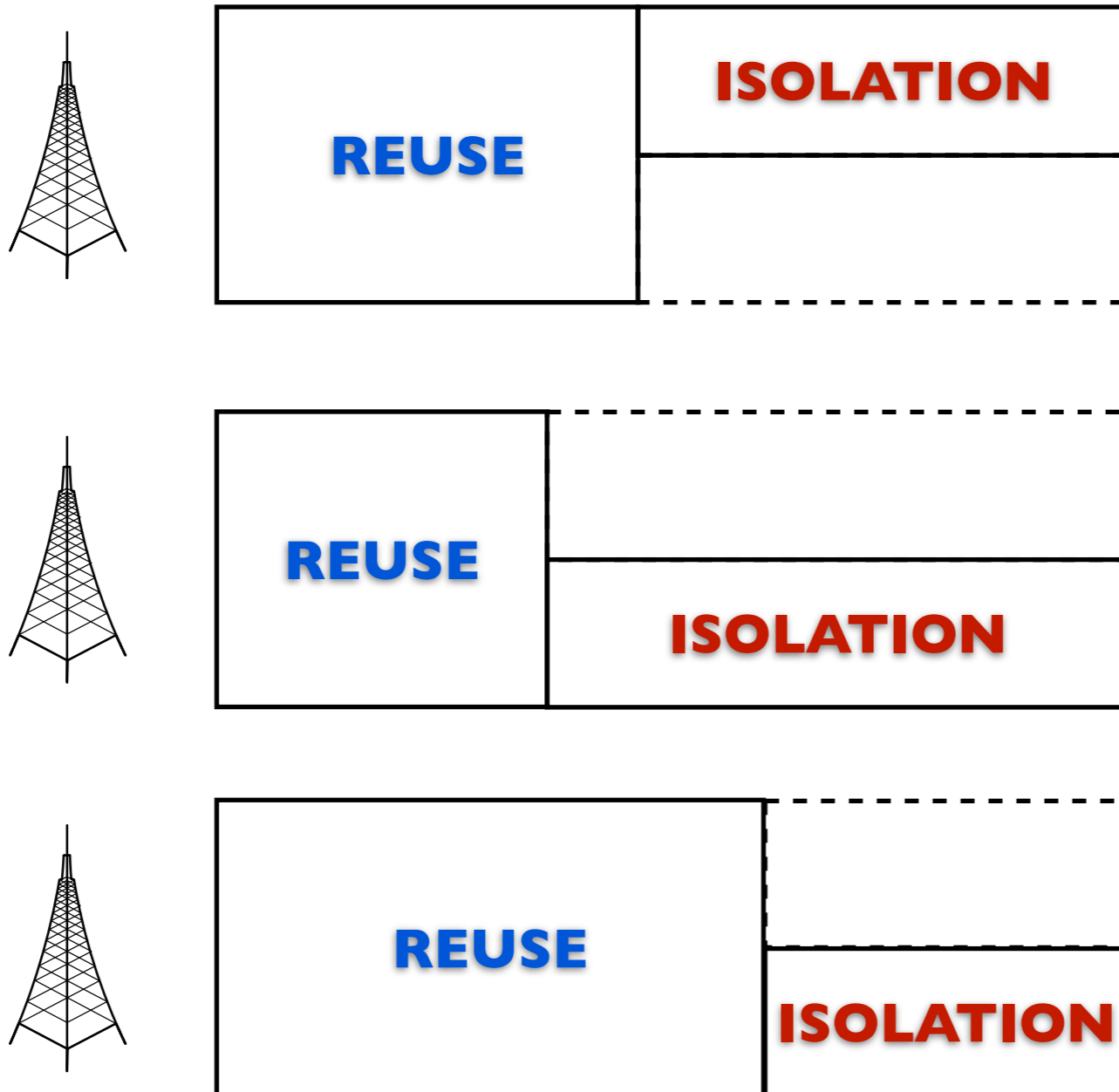
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- **FERMI guarantees a feasible coloring!**

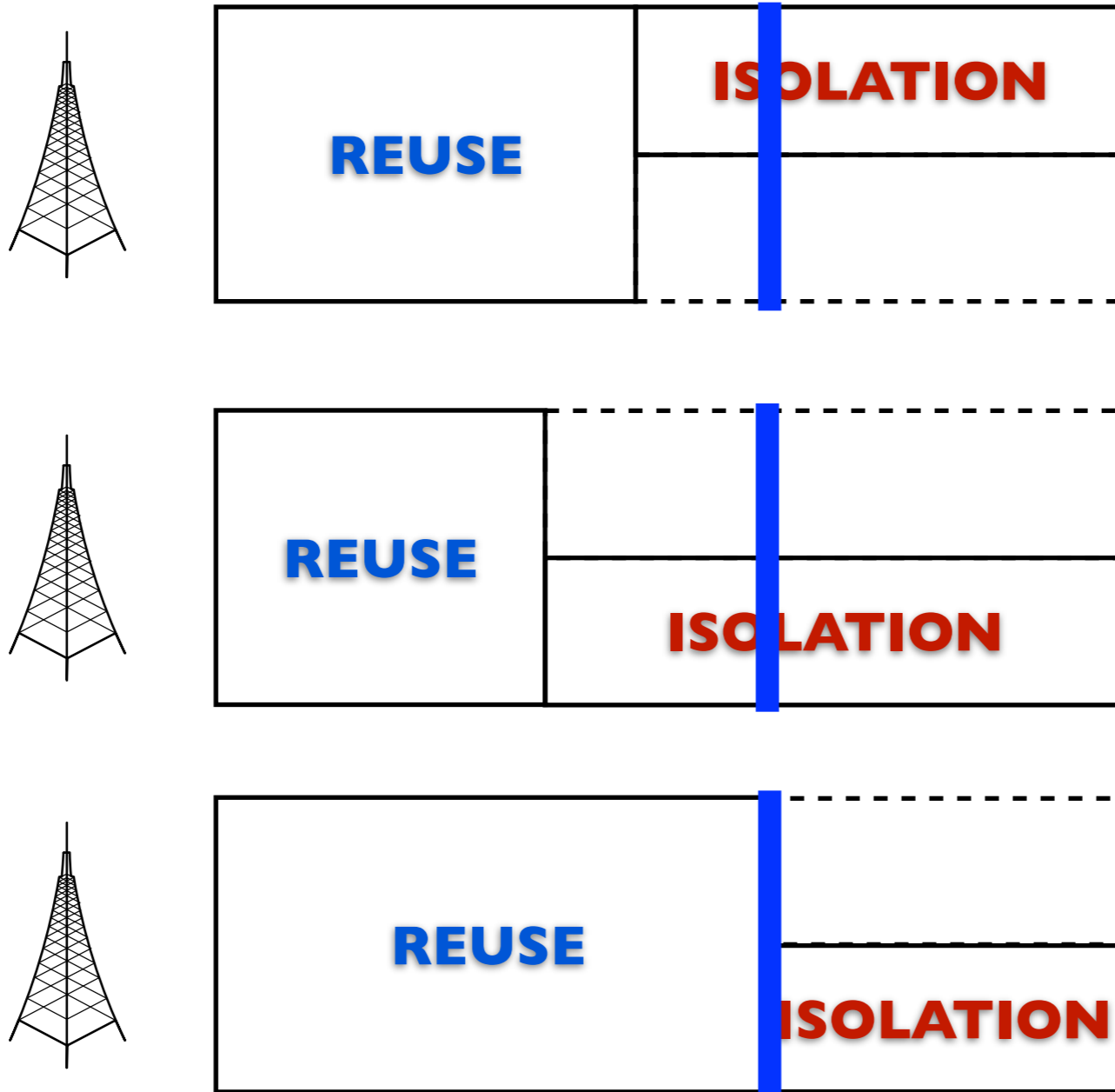
Zoning

- Common reuse zone size: min or max?



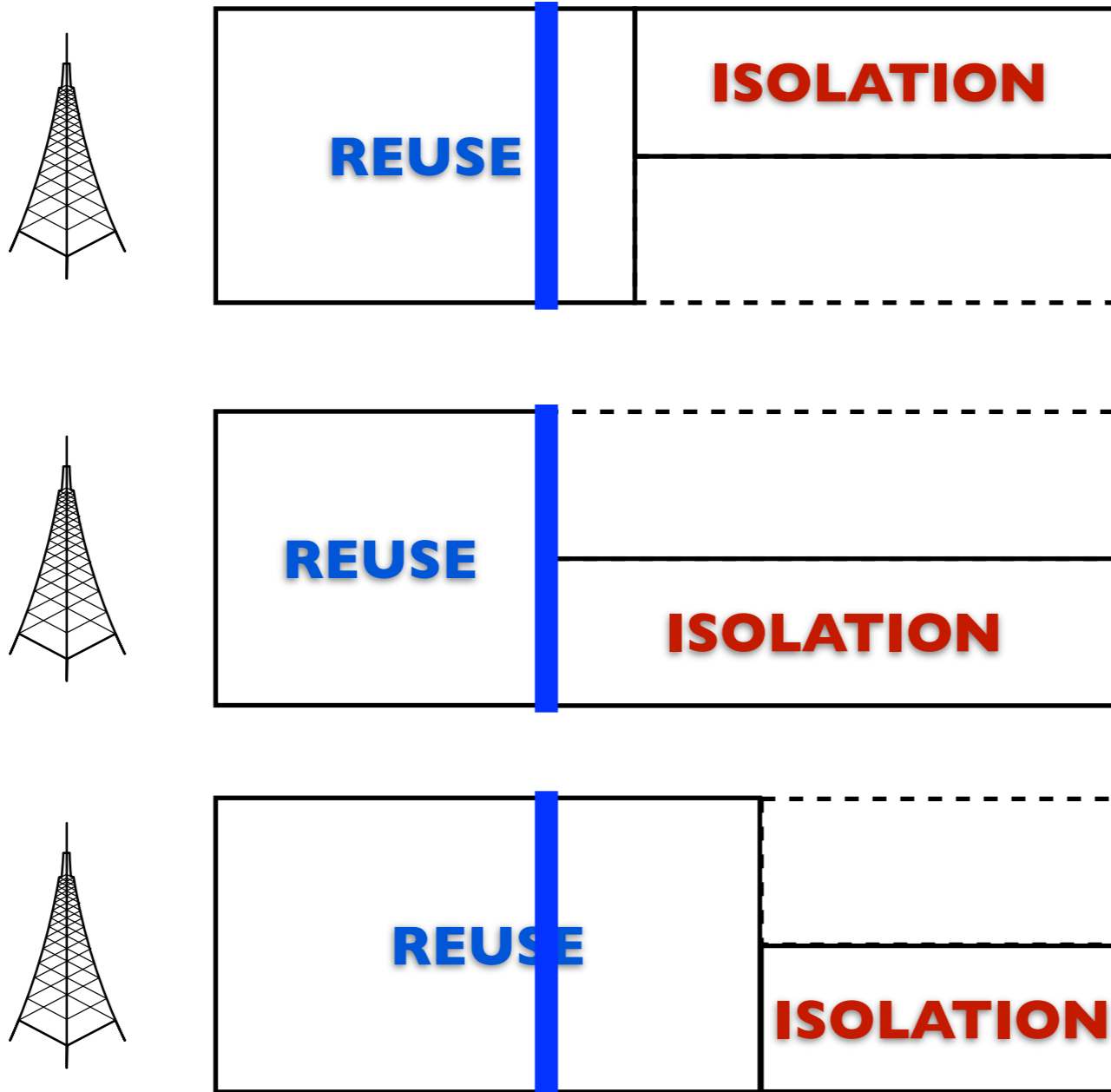
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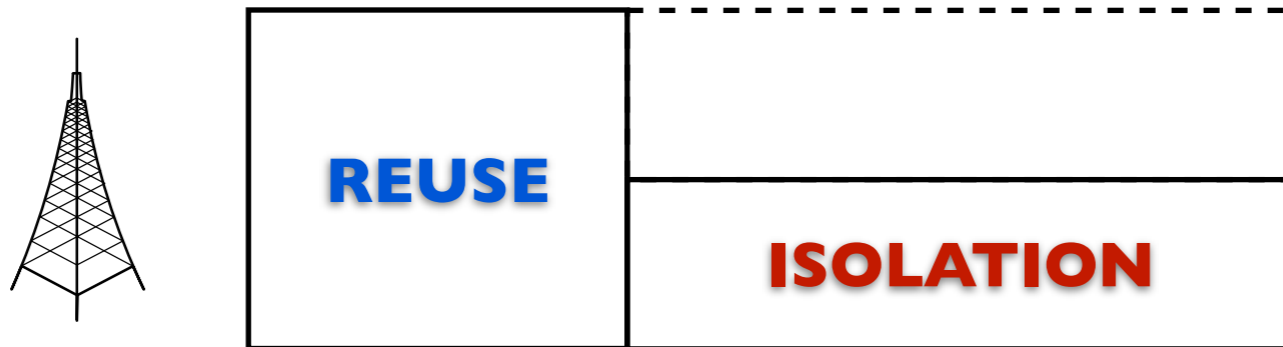
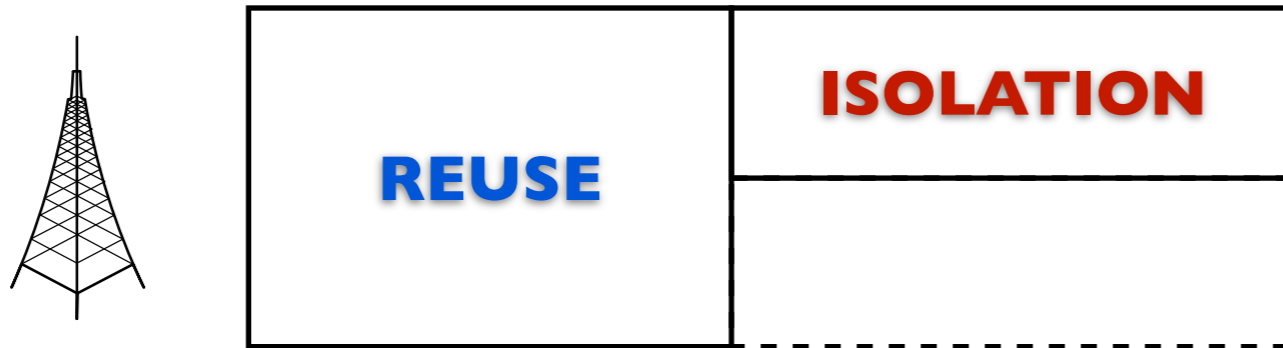
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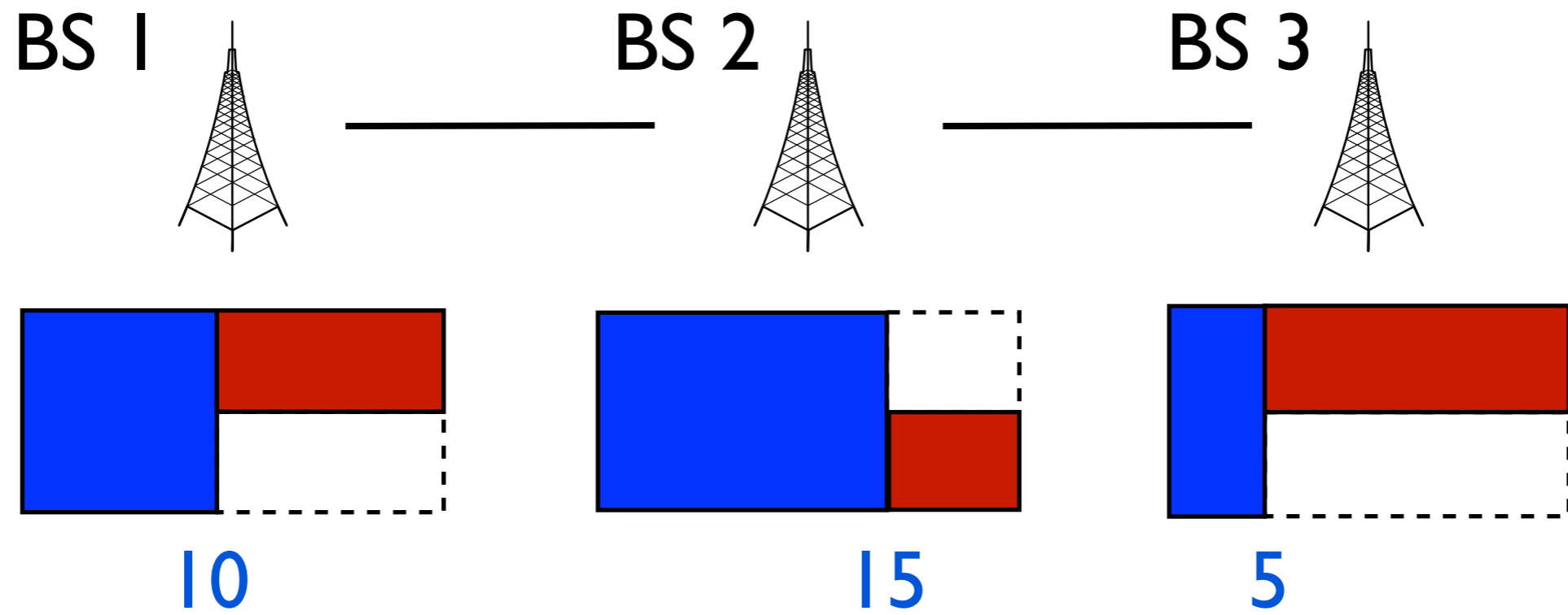
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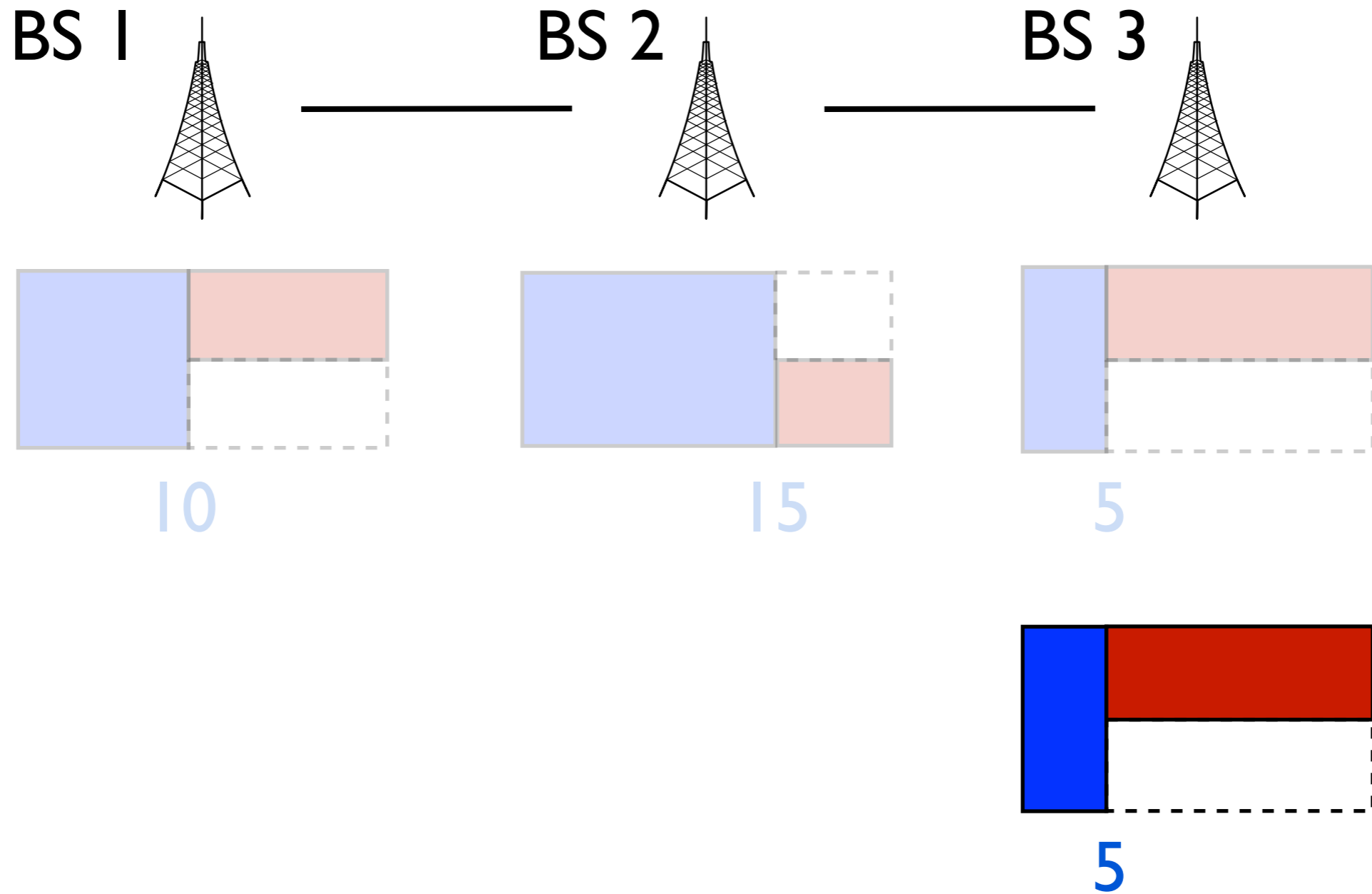


**AVOID
CASCADES!**

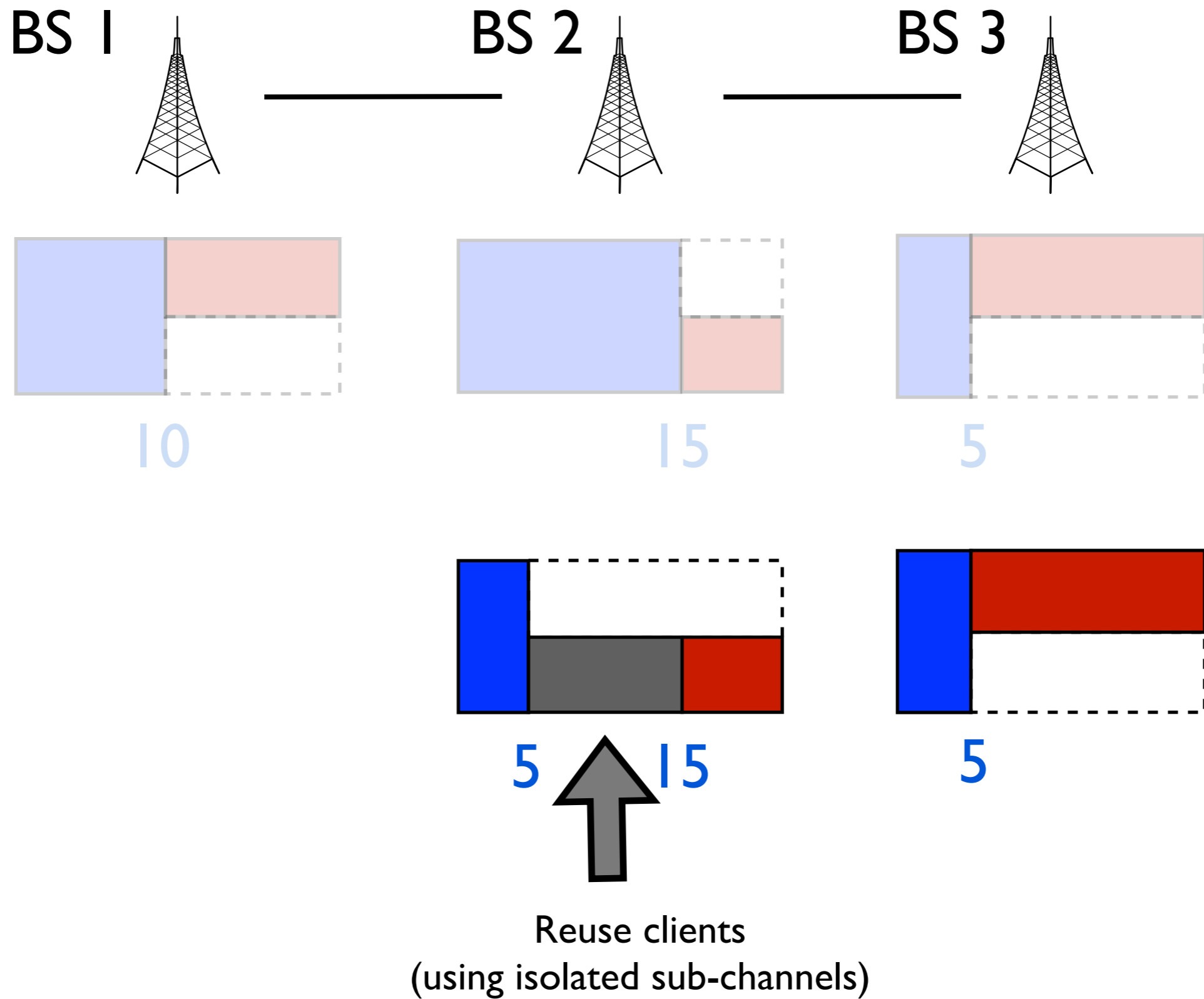
Zoning (avoiding cascades)



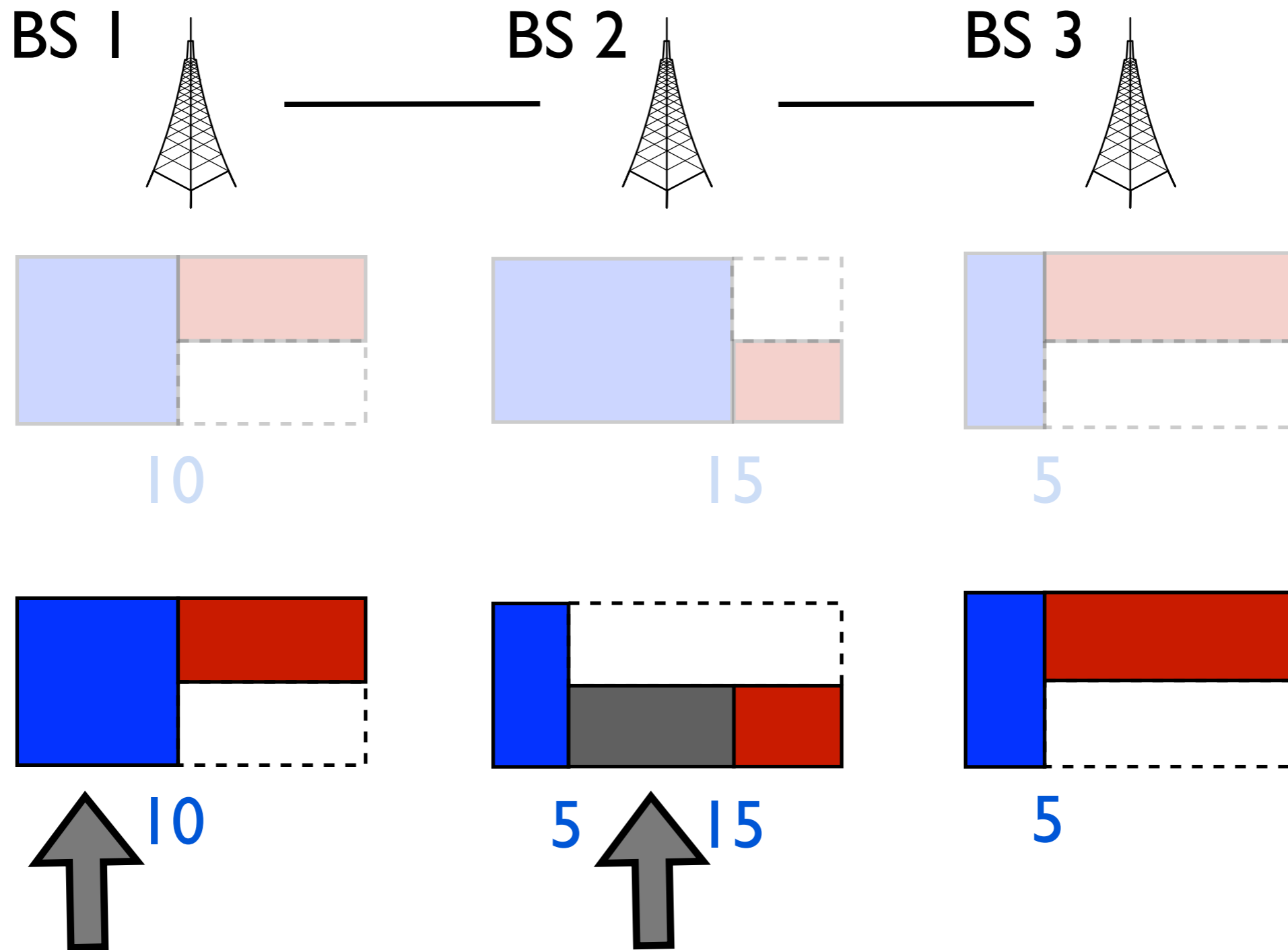
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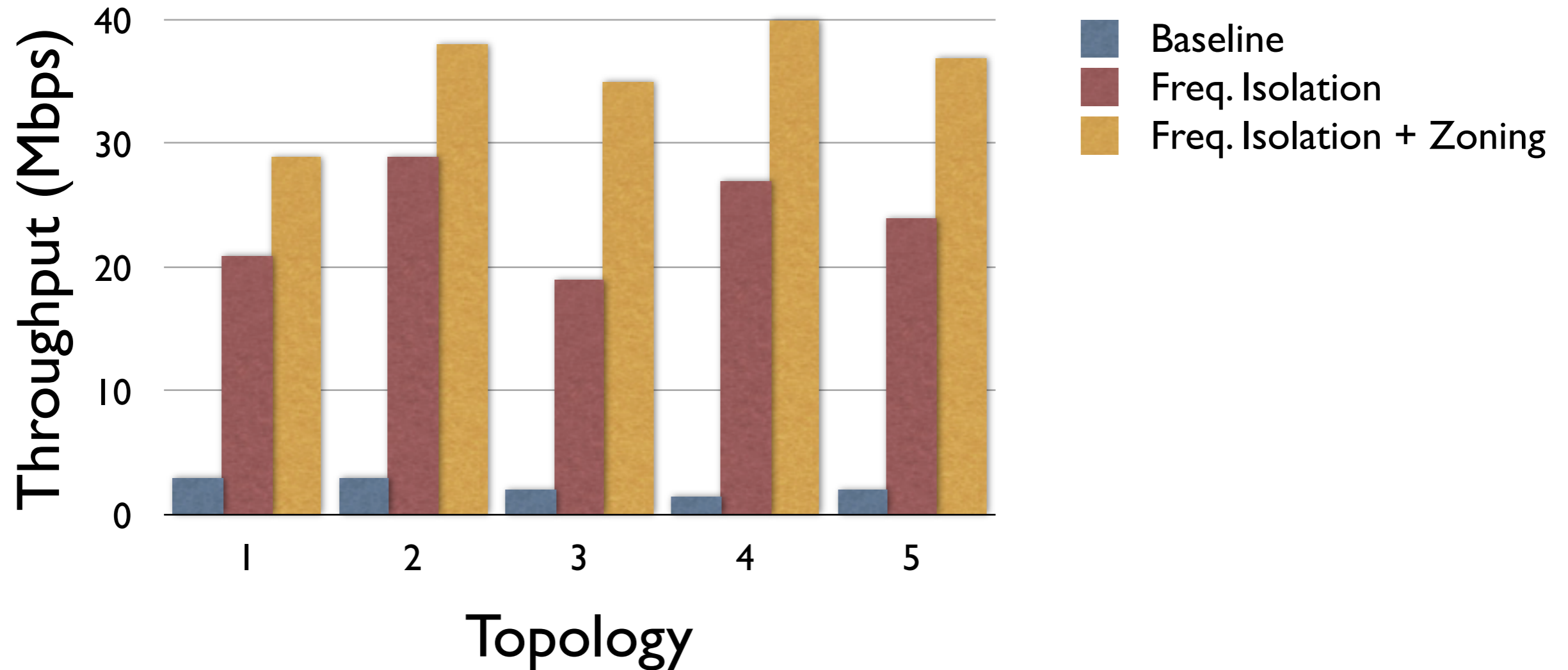
Cascade avoided since no interference to BS2's clients

Reuse clients (using isolated sub-channels)

Roadmap

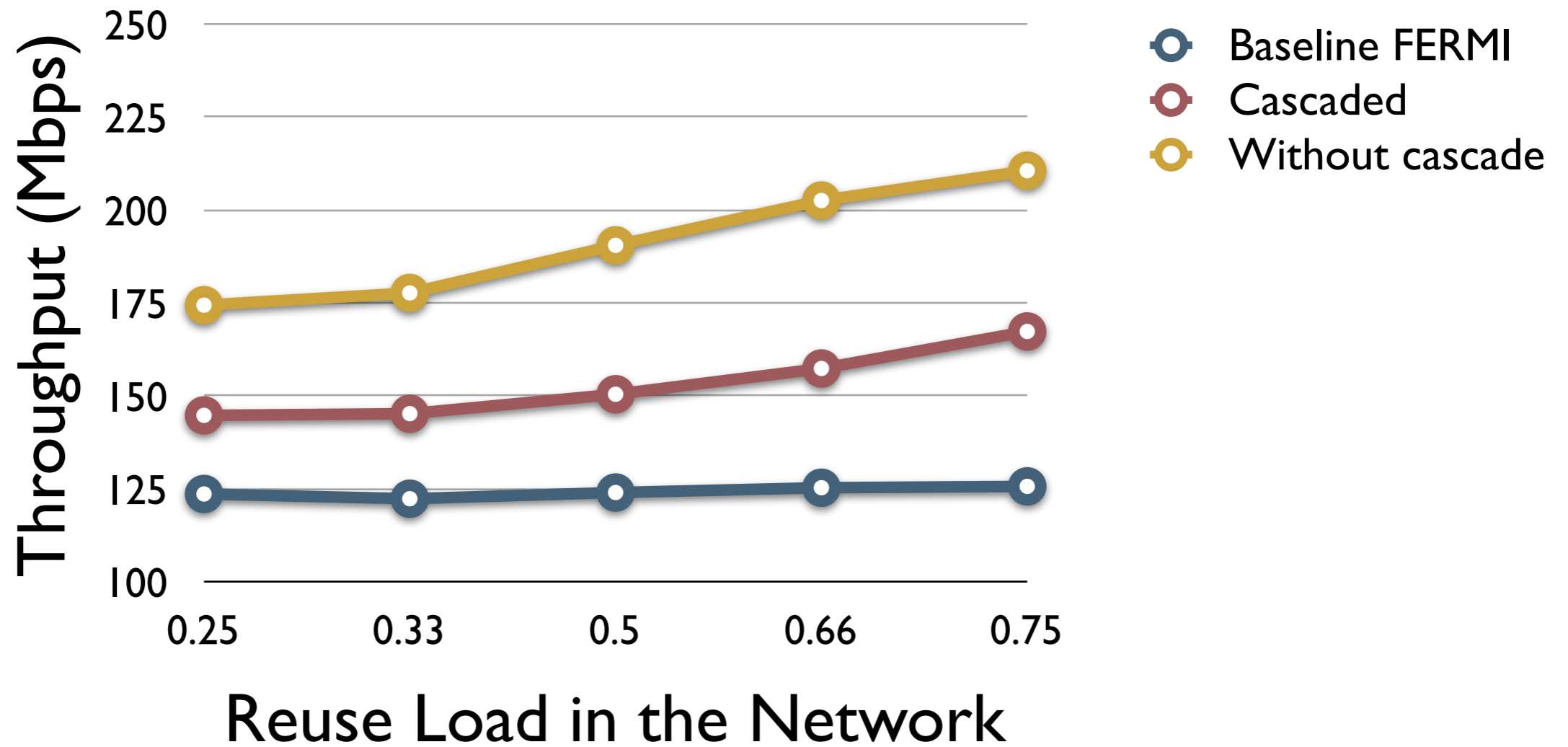
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Evaluation



- Zoning provides around 50% throughput gain over pure sub-channel isolation.

Evaluation



- Avoiding cascades provides 30% gain over cascaded zoning.

Conclusion

- FERMI mitigates interference among femtocells in an enterprise. The distinguishing aspects are:
 - ✓ Identify tolerance of clients to interference.
 - ✓ Flexible Frame structure to support the graceful coexistence of clients (reuse and isolation).
 - ✓ Novel use of chordal graphs to achieve near optimal allocation and feasible assignment.
 - ✓ Intelligent zoning to mitigate interference and leverage reuse at the same time.
 - ✓ Implemented, evaluated on a WiMAX testbed (concepts applicable to LTE as well.).

Thank you!

- Questions?