RADION: A Distributed Resource Management Framework for Interference Mitigation in OFDMA Femtocell Networks

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Motivation for femtocell

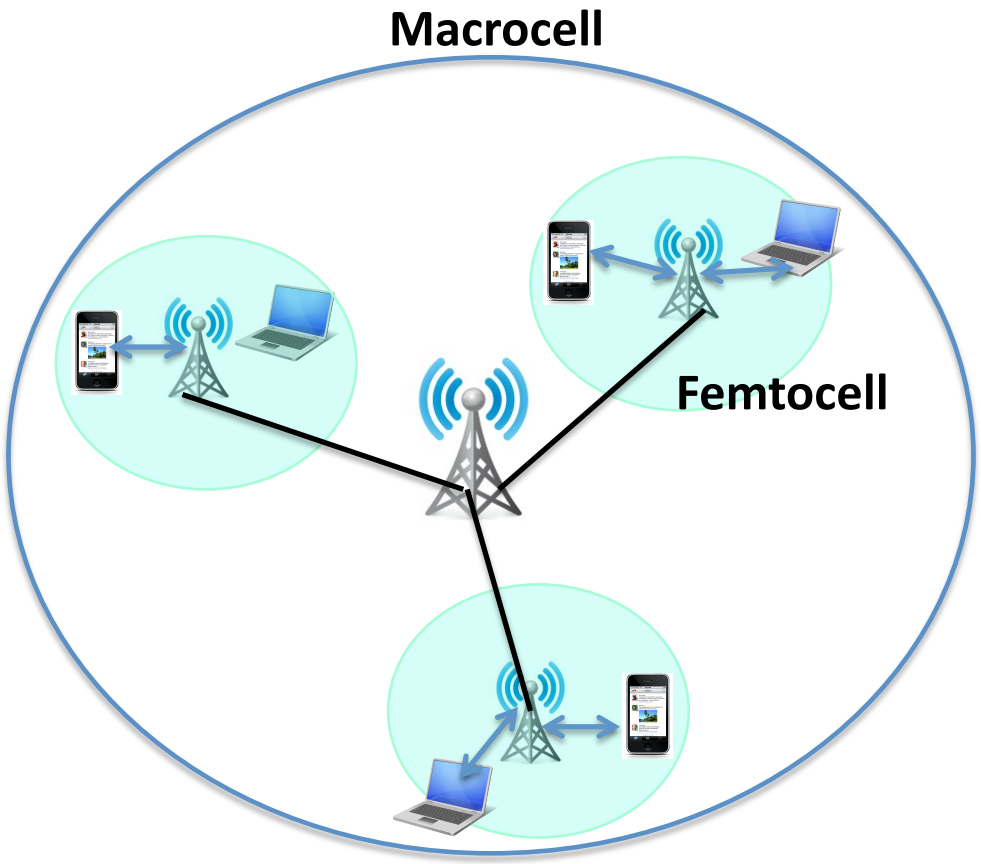
- Mobile data usage will grow by a factor of 26 by 2015*
- More than 50% of voice calls and more than 70% of data traffic originate indoors**
- For indoor devices, attenuation losses will make high signal quality and hence high data rates very difficult to achieve

Femtocell for better performance and coverage indoors

* Cisco Vis

** Present *Home Acces* s.html

Femtocells



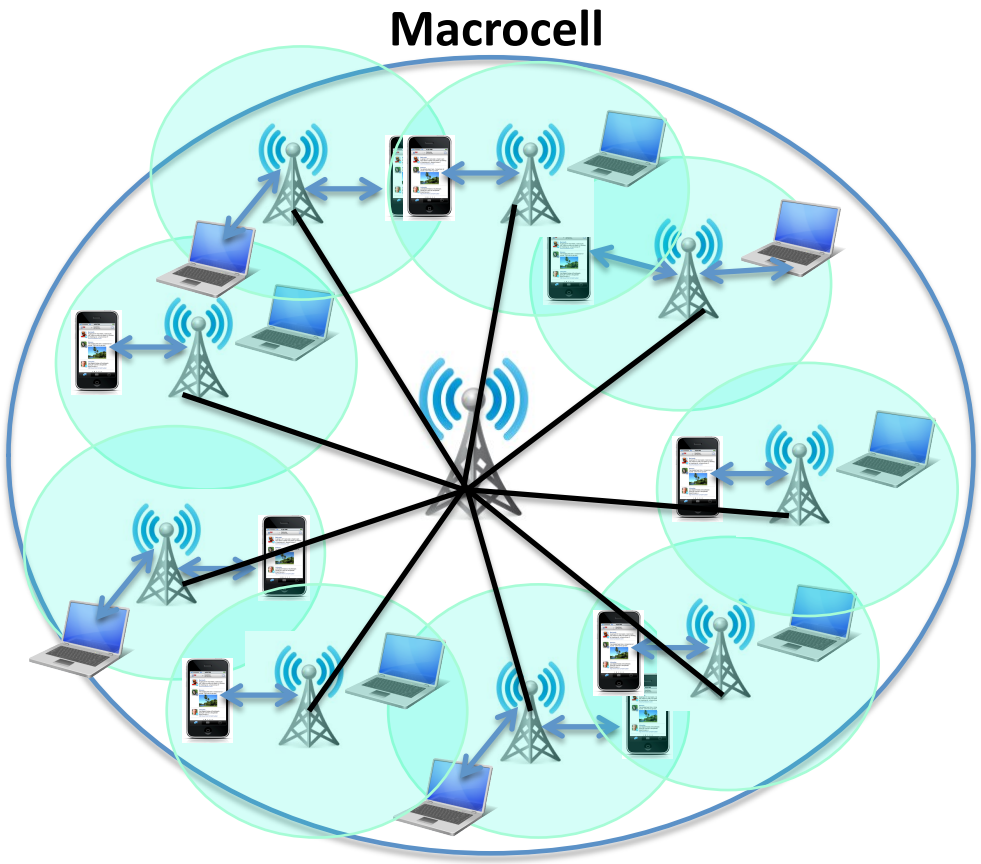
- Short range, low cost and low power home typed cellular Base Station
- Installed indoor, use cable/DSL backhaul
- Reuse macro spectrum

✓ Coverage (higher quality link)

✓ Spatial efficiency

✓ Lower power

Femtocells in dense deployment



- ✓High Interference among neighboring femtocells
  → degraded performance
- ✓Lack of coordination
  → inefficient resource operation

Centralized resource management

- FERMI [Mobicom ’11] in enterprise setting
- Multiple femtocells assume to cooperate towards a network-wide objective
- Requires centralized collection of the global network view and information exchanges
- Resources will be assigned by a centralized controller

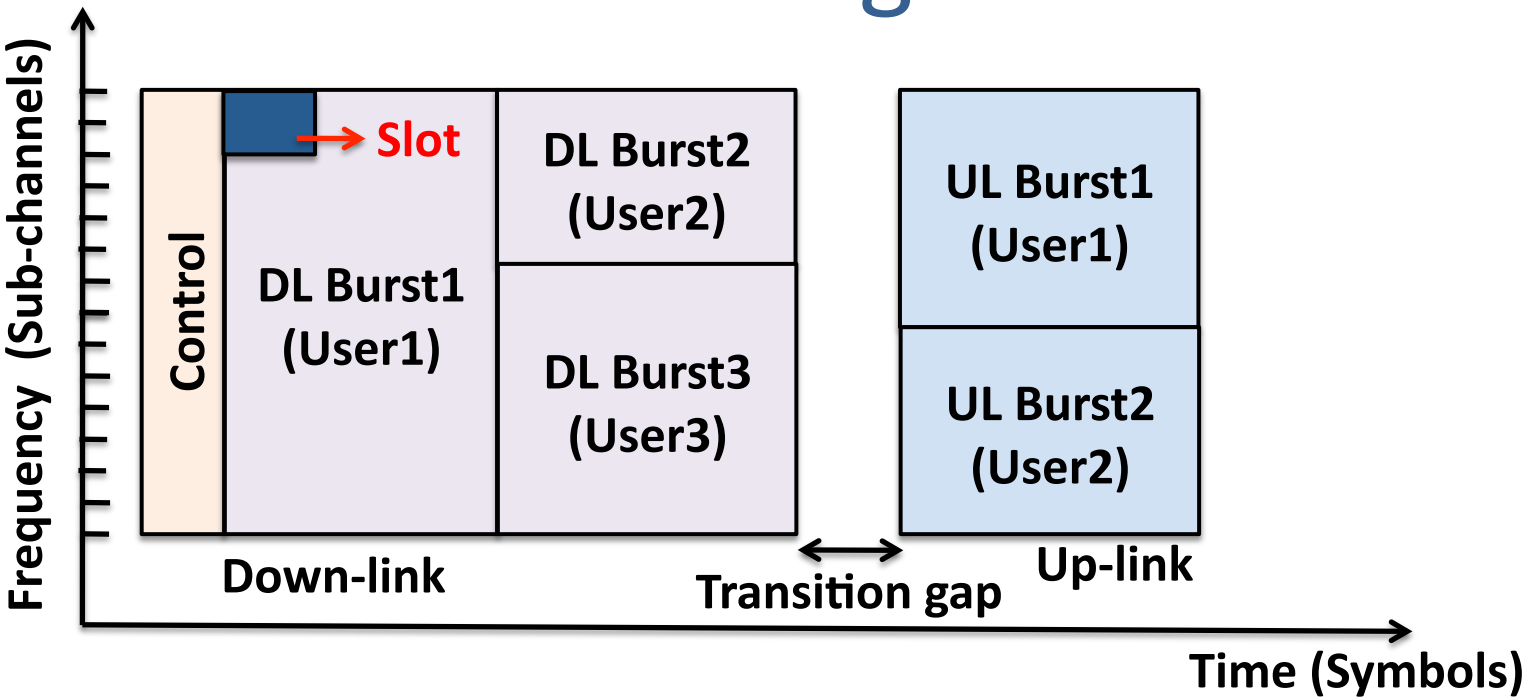
Distributed resource management

- No coordination (interaction) is needed
- Suitable for unplanned residential deployment
- No overhead for collecting interference map
- Each femto base-station can intelligently find the available resources in an opportunistic manner
- Adapts to the network dynamics quickly

Outline

- Introduction
- WiMAX background
- Challenges and our solutions
  - Scheduling multiple clients in the same frame
  - Resource coupling across the femtocells
  - Resource allocation
- Evaluation
- Conclusion

WiMAX background



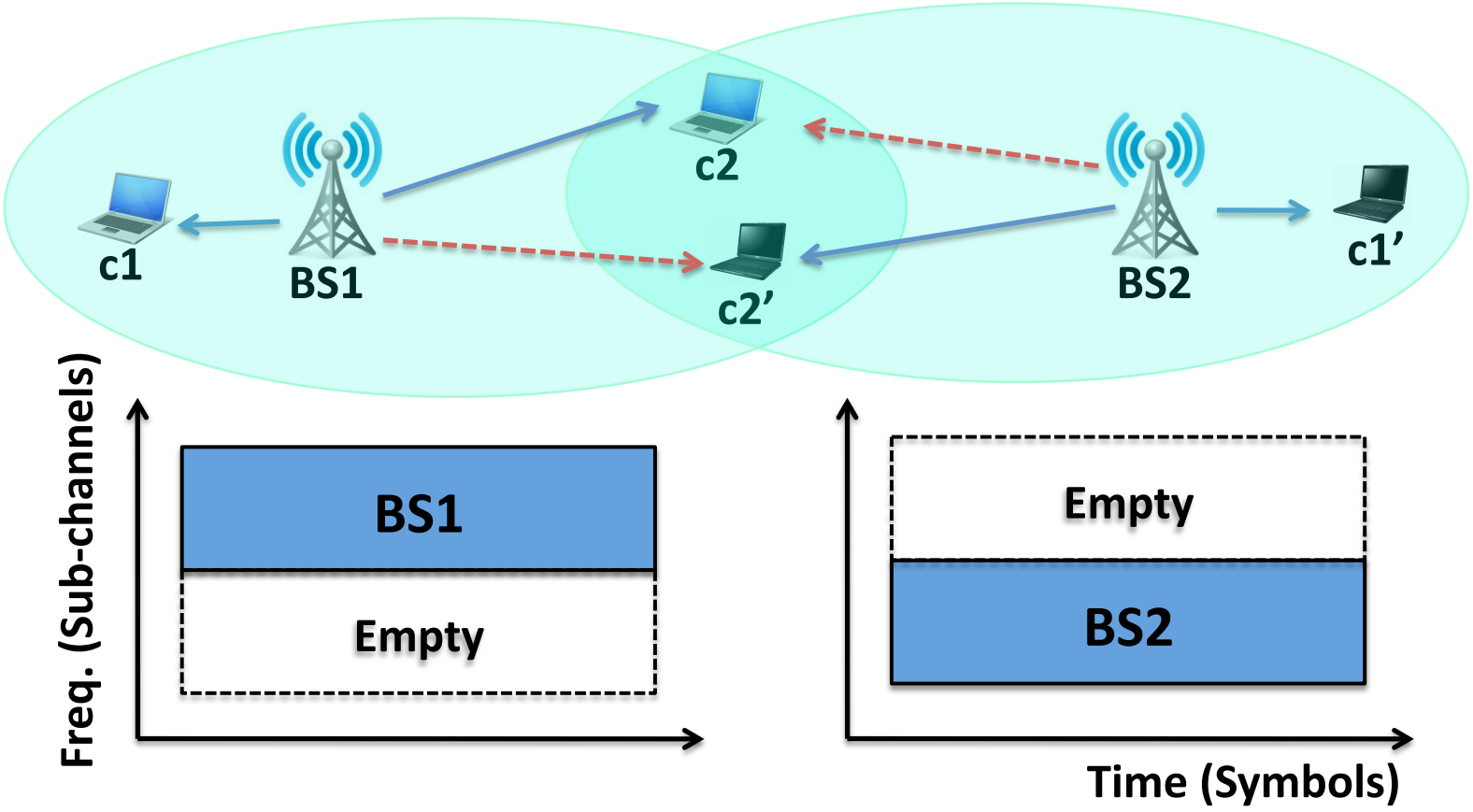
- Scheduling multiple users in the same frame
- No carrier sensing
- Rigid frame structure and timing

Challenges

1. Scheduling multiple clients in the same frame

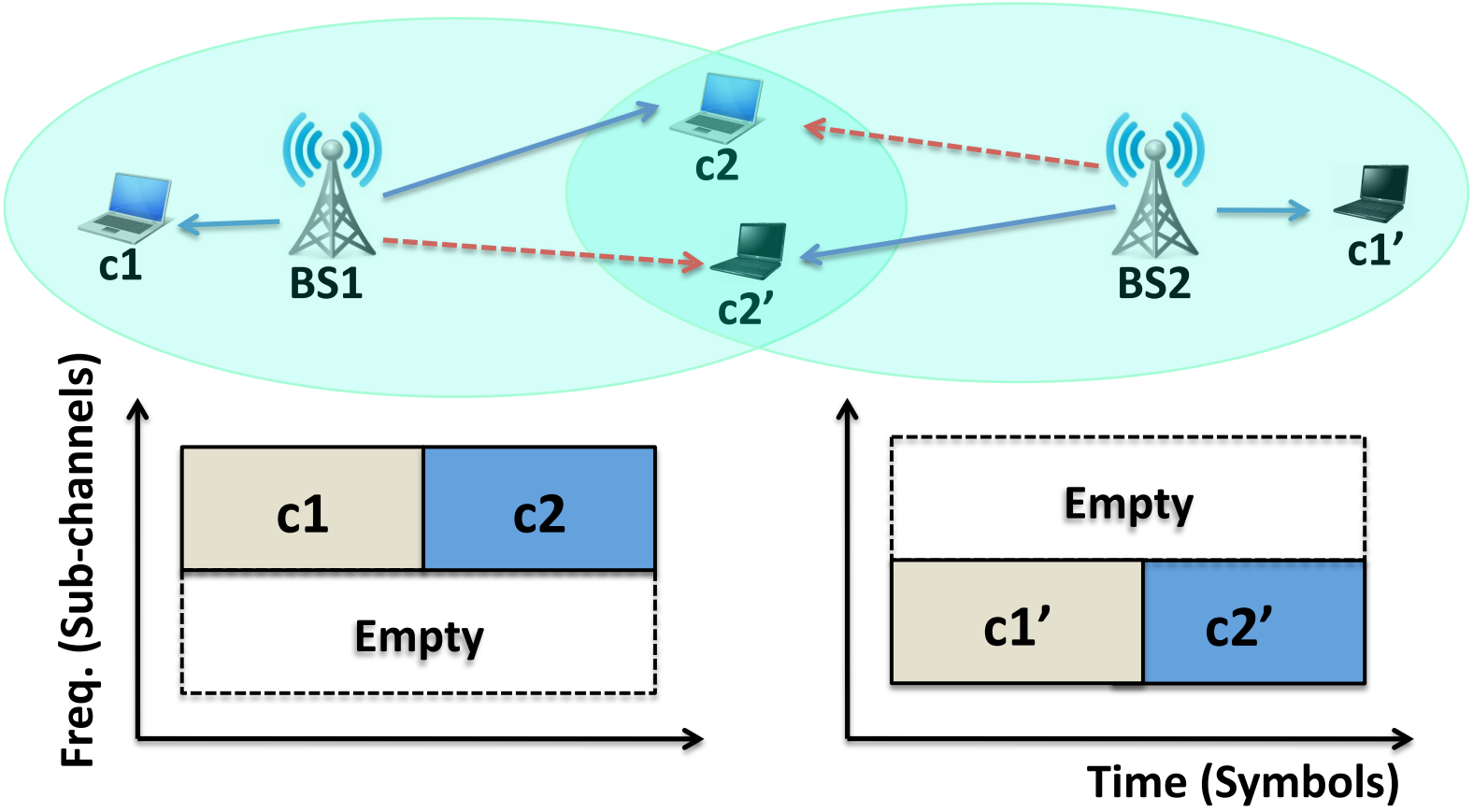
Interference mitigation

- Using different sub-channels



Scheduling multiple clients

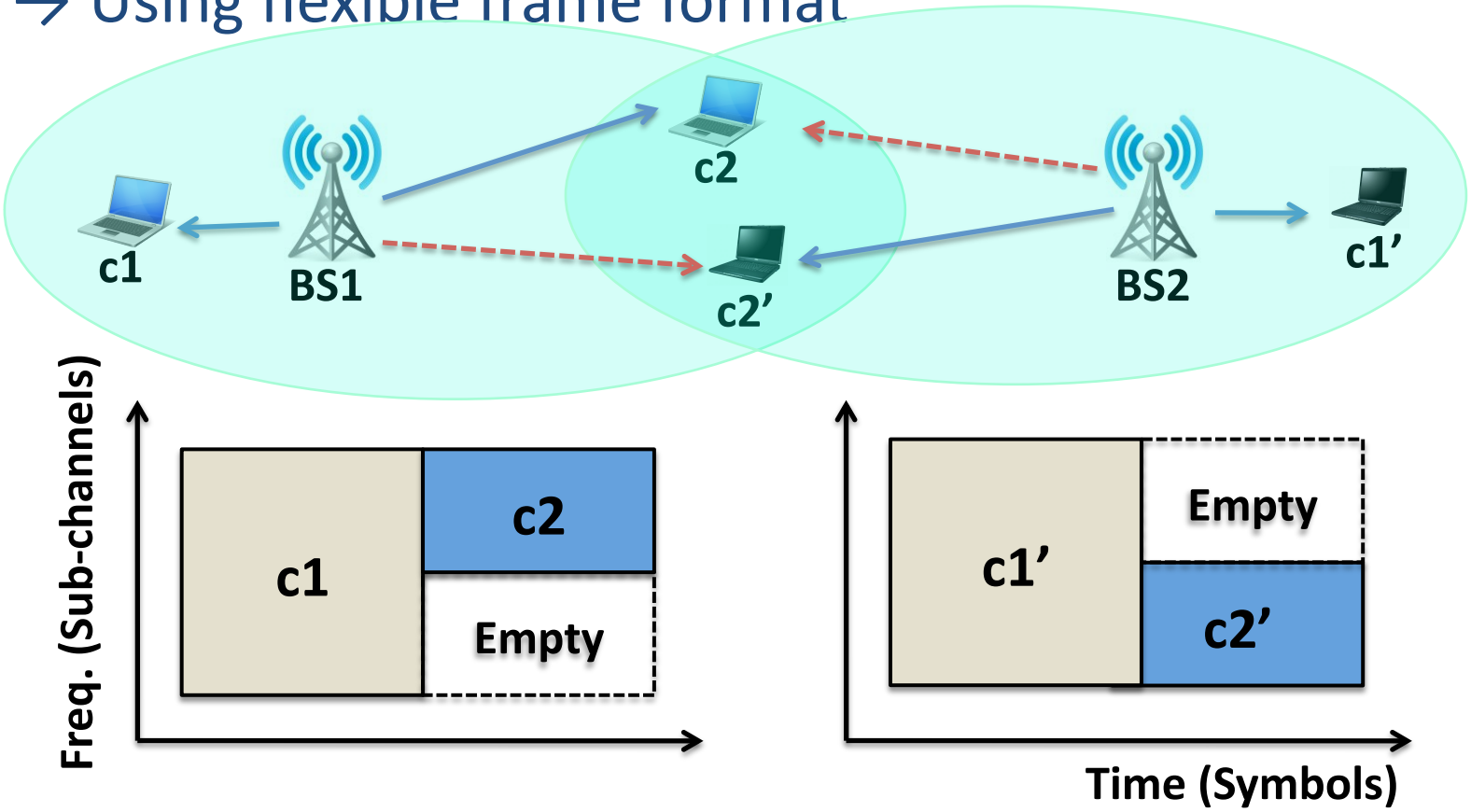
- Using different data bursts to different clients



Zoning

- Promoting efficient use of spectrum

  → Using flexible frame format



Zoning

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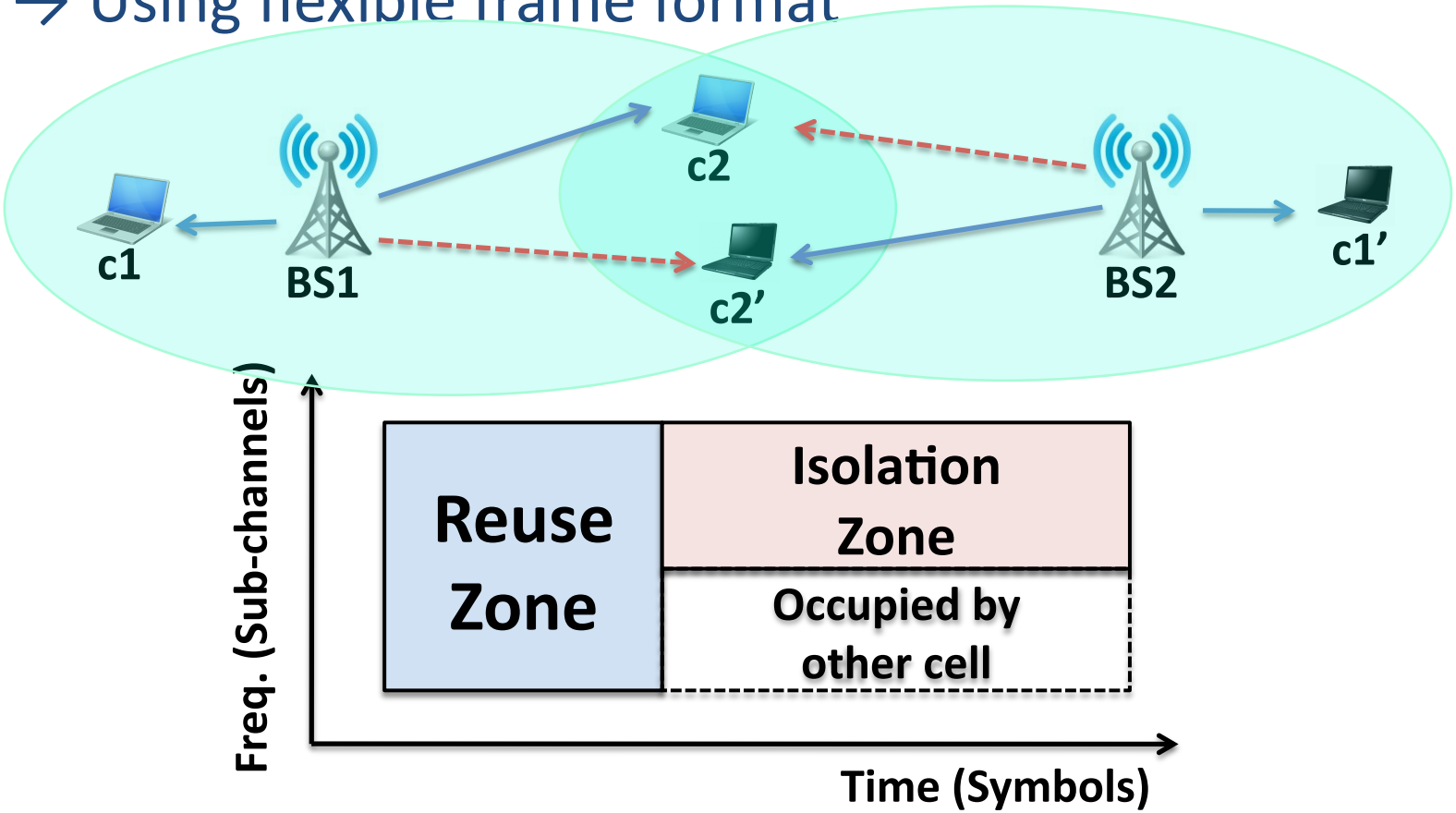


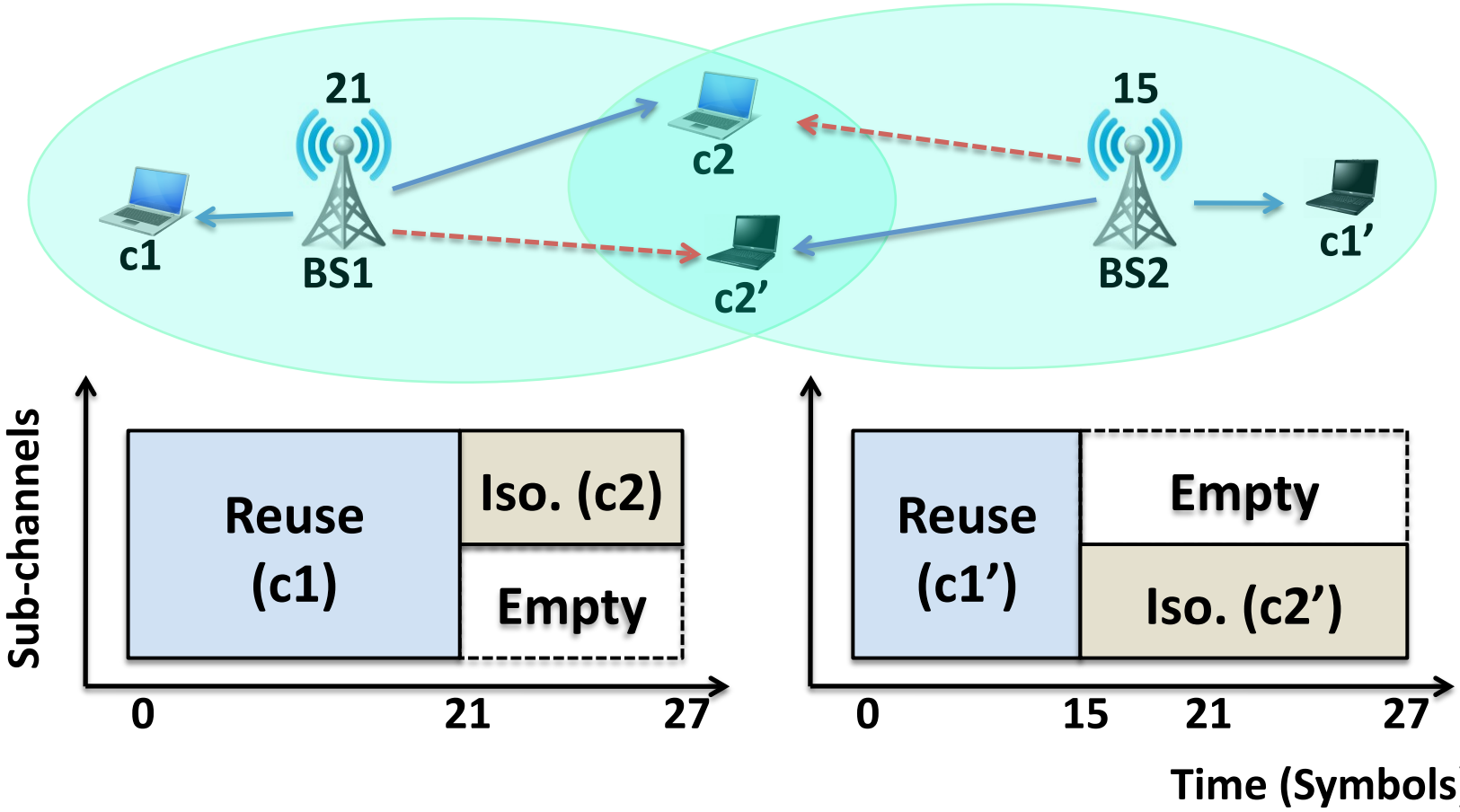
Challenges and Solutions

1. Scheduling multiple clients in the same frame
   → Zoning (Reuse and Isolation zones)

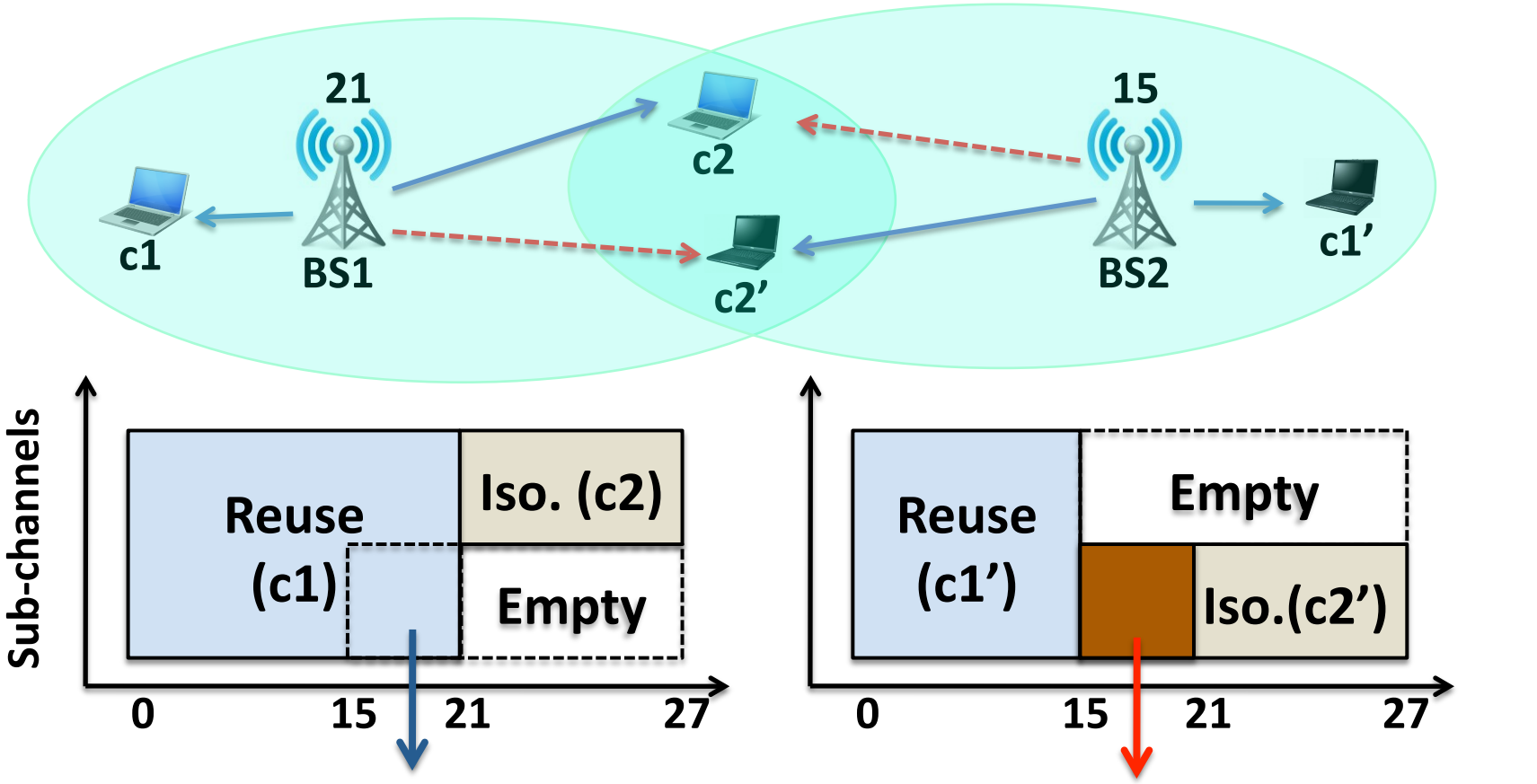
Challenges

1. Scheduling multiple clients in the same frame
   → Zoning (Reuse and Isolation zones)
2. Resource coupling across the femtocells

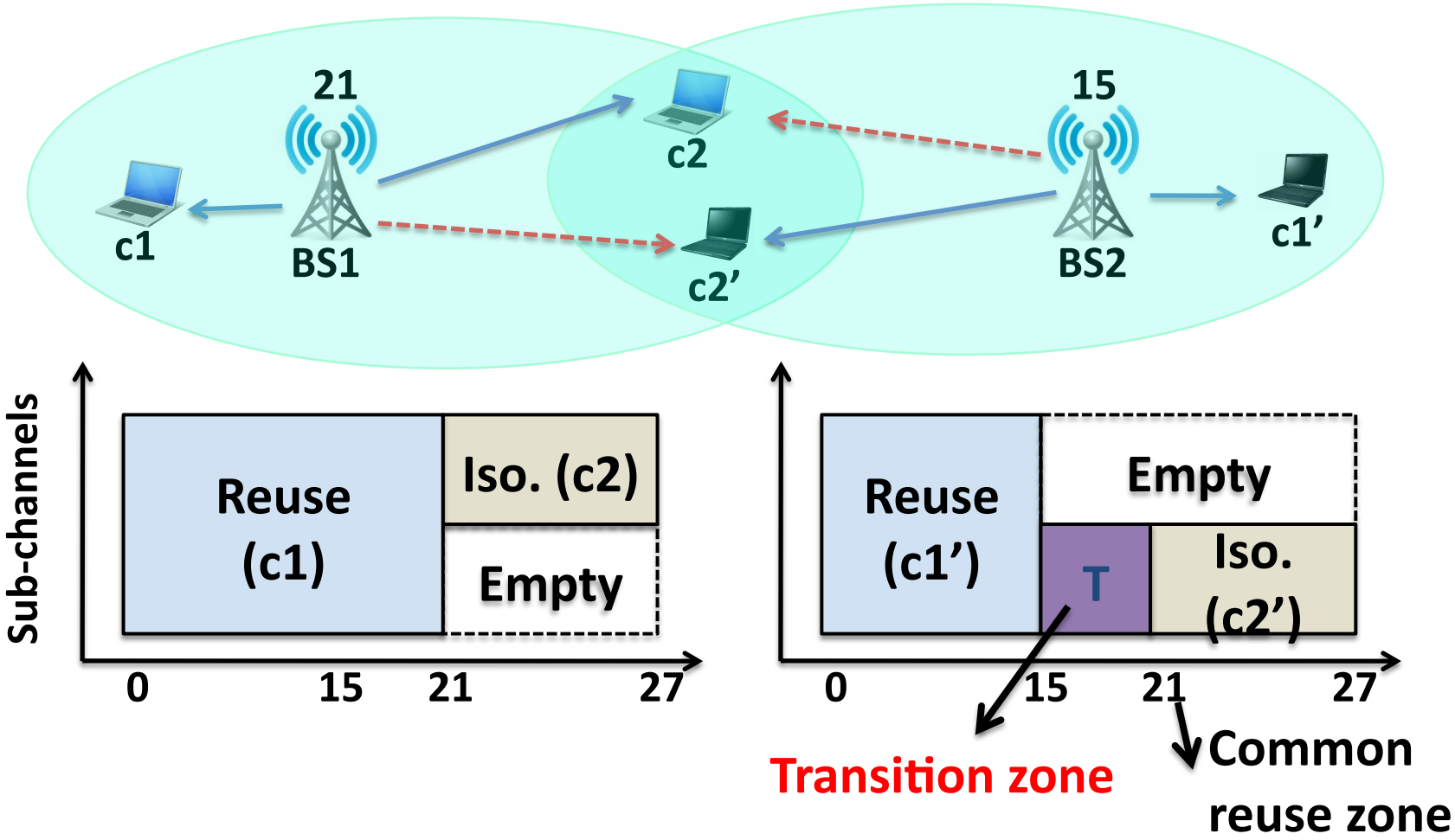
Zoning


21
15
c2
c1
BS1
c2'
BS2
c1'
Sub-channels
Reuse (c1)
Iso. (c2)
Empty
0
21
27
Reuse (c1')
Empty
Iso. (c2')
0
15
21
27
Time (Symbols)

Interference on isolation zone

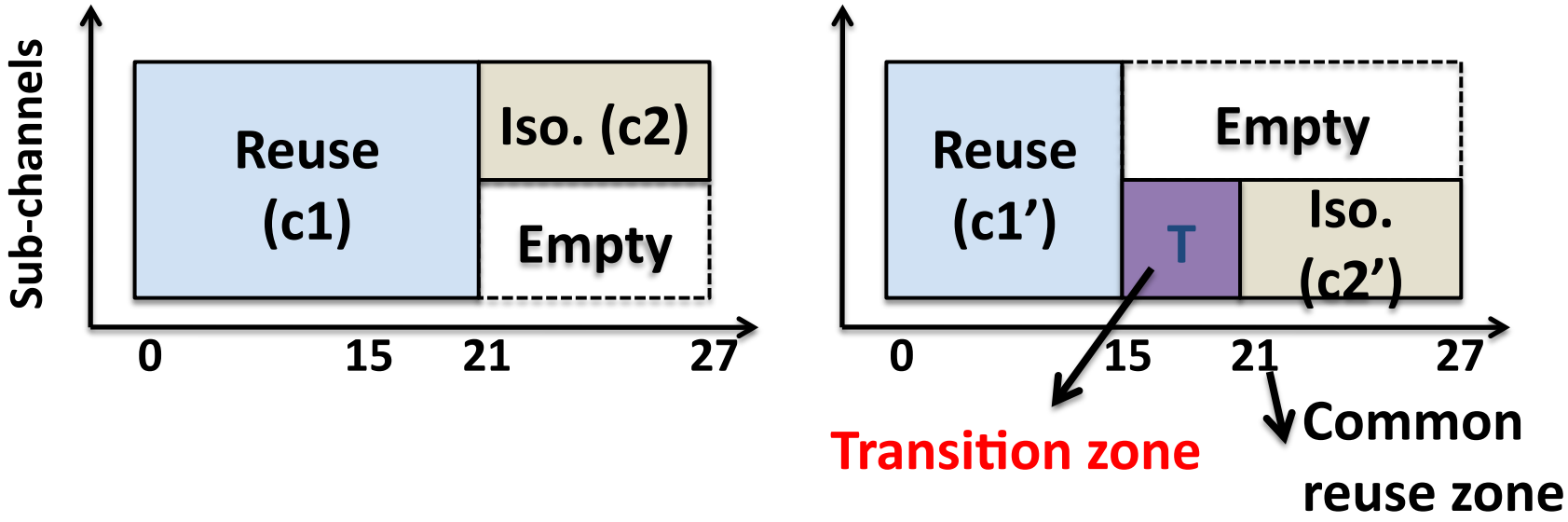


Transition zone



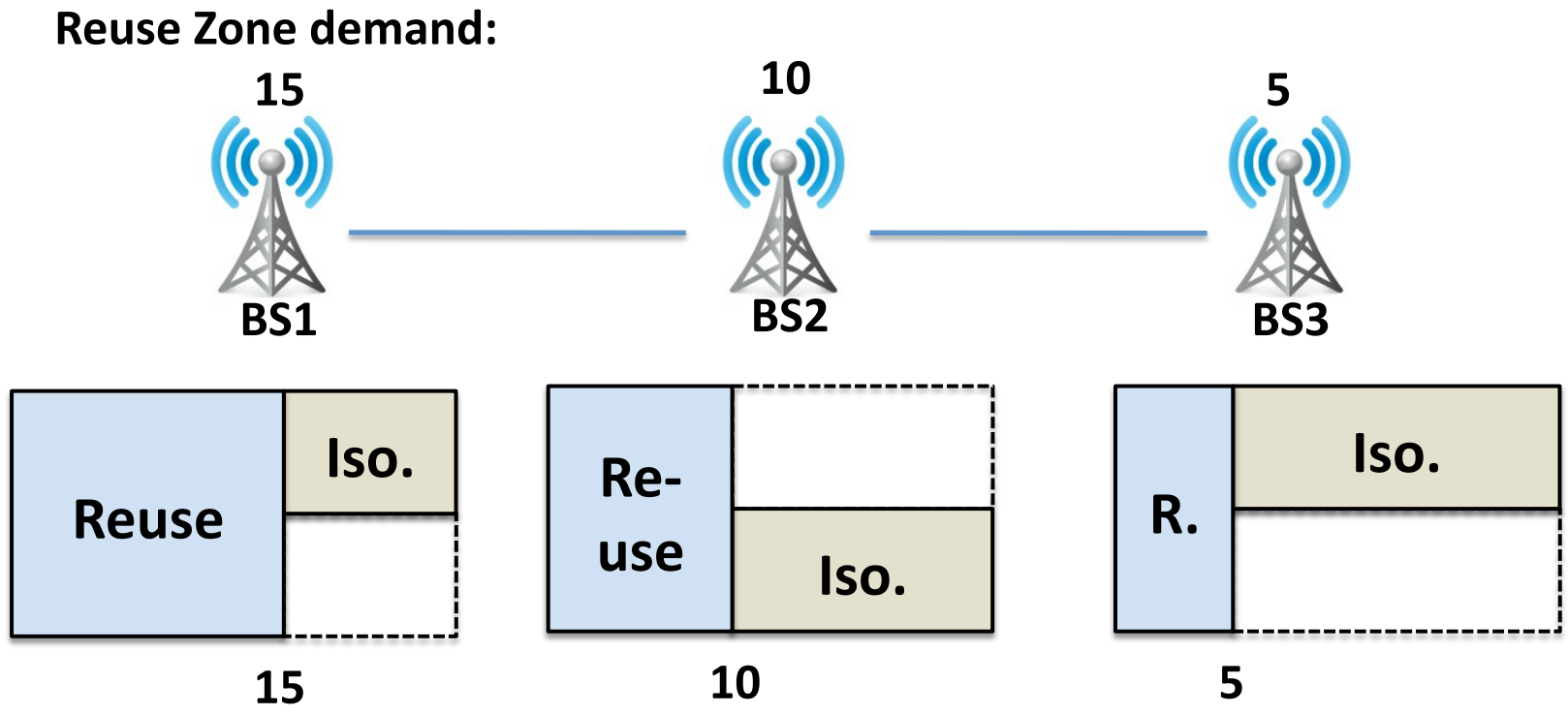
Benefits of transition zone (1)

Allows clients to reuse resources without incurring interference



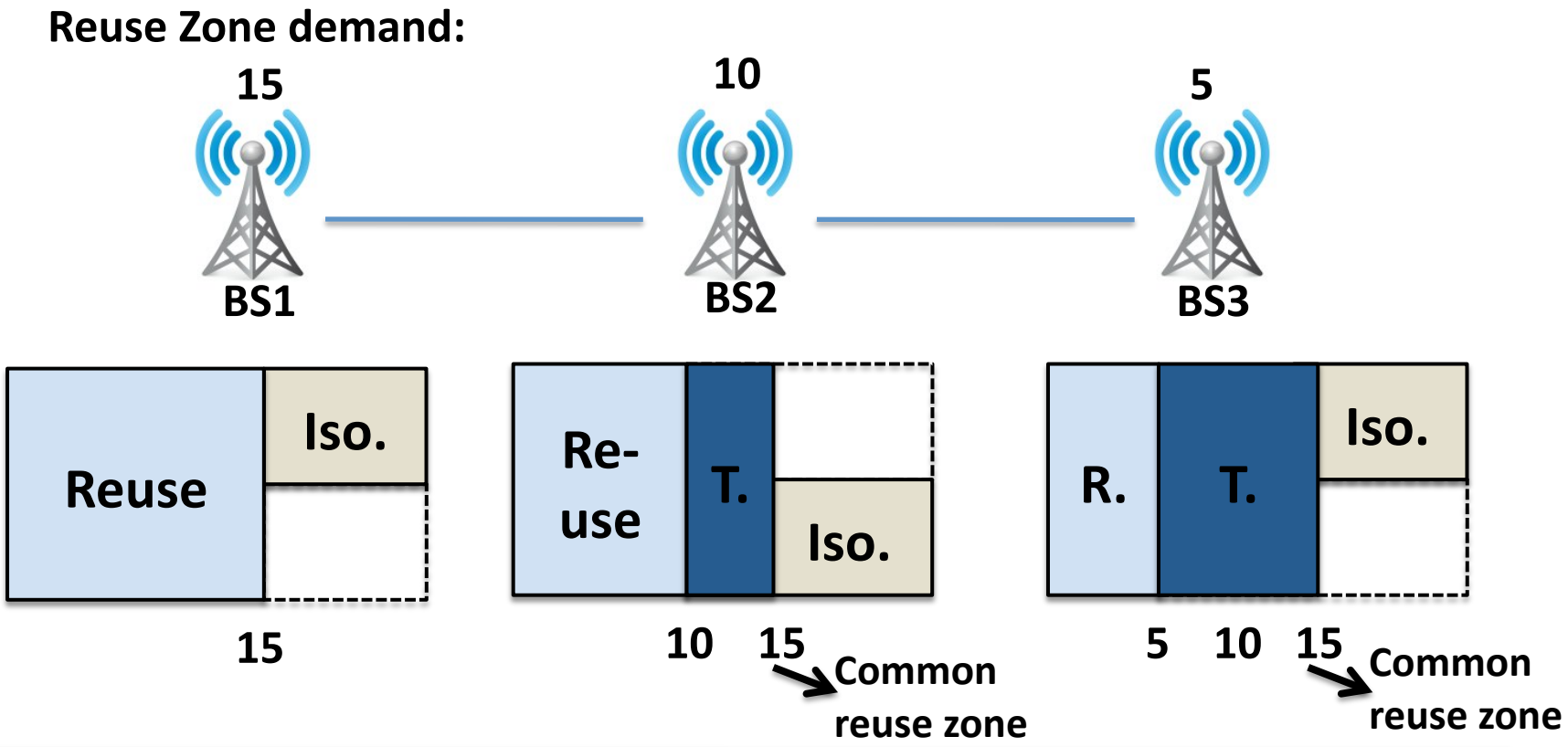
Three femtocells deployment

- Preventing propagation



Propagation of reuse zone

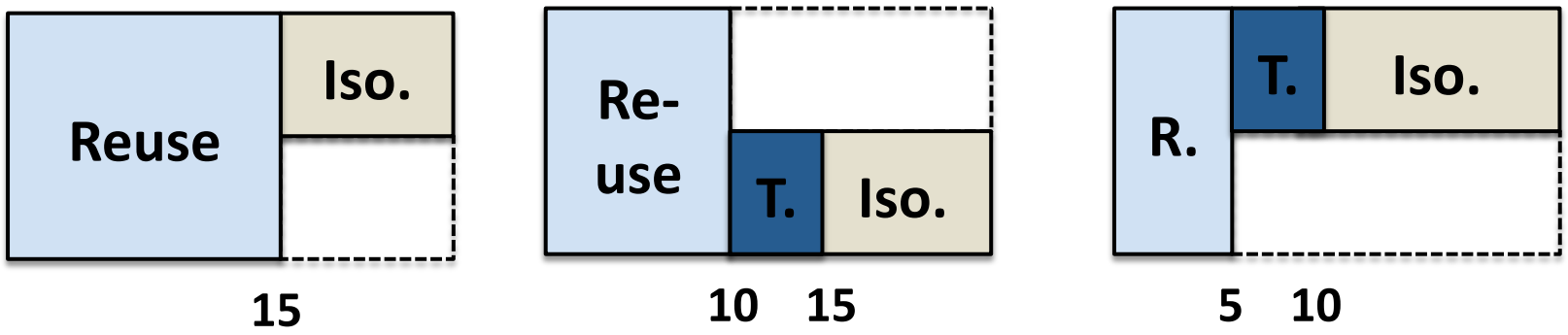
- Resource coupling



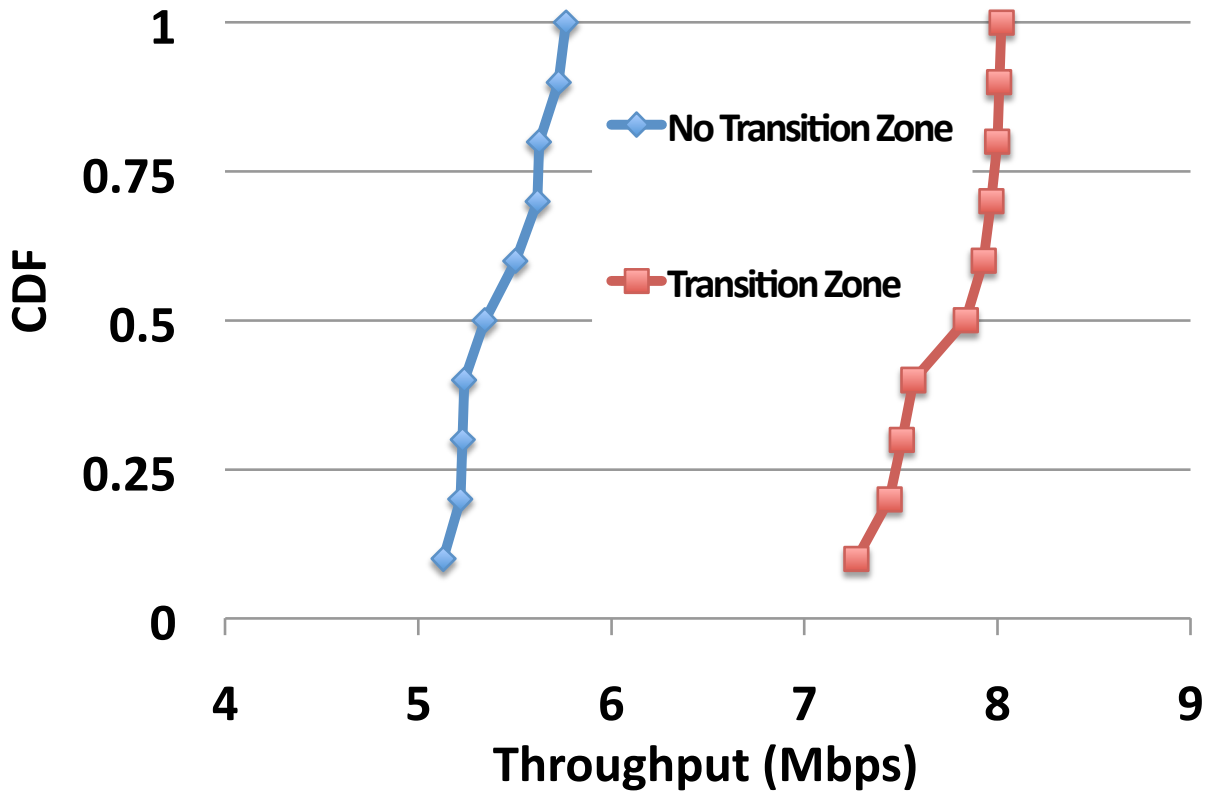
Benefits of transition zone (2)

- Preventing propagation

Transition zone prevents the common reuse zone from propagating to the network



Throughput improvement



42 % Throughput Improvement

Challenges and solutions

1. Scheduling multiple clients in the same frame
   → Zoning (Reuse and Isolation zones)

2. Resource coupling across the femtocells
   → Transition zone

Challenges

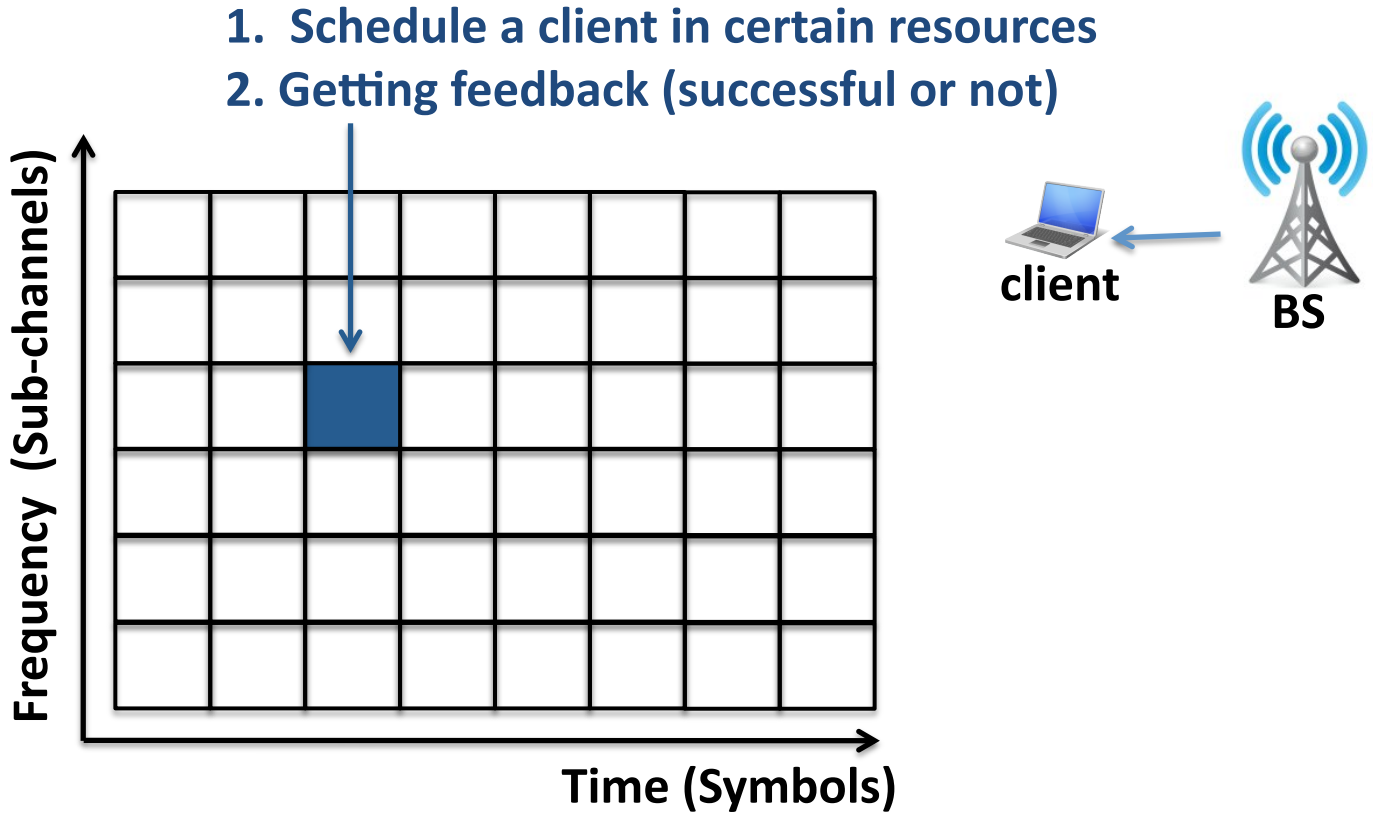
1. Scheduling multiple clients in the same frame
   → Zoning (Reuse and Isolation zones)
2. Resource coupling across the femtocells
   → Transition zone
3. Distributed resource allocation framework

Goal of algorithm

- Each femtocell determines its zone sizes and resource usage in a completely distributed manner.
- Each femtocell adapts to network dynamics quickly and efficiently.

Probing

- Identifying the availability of resources



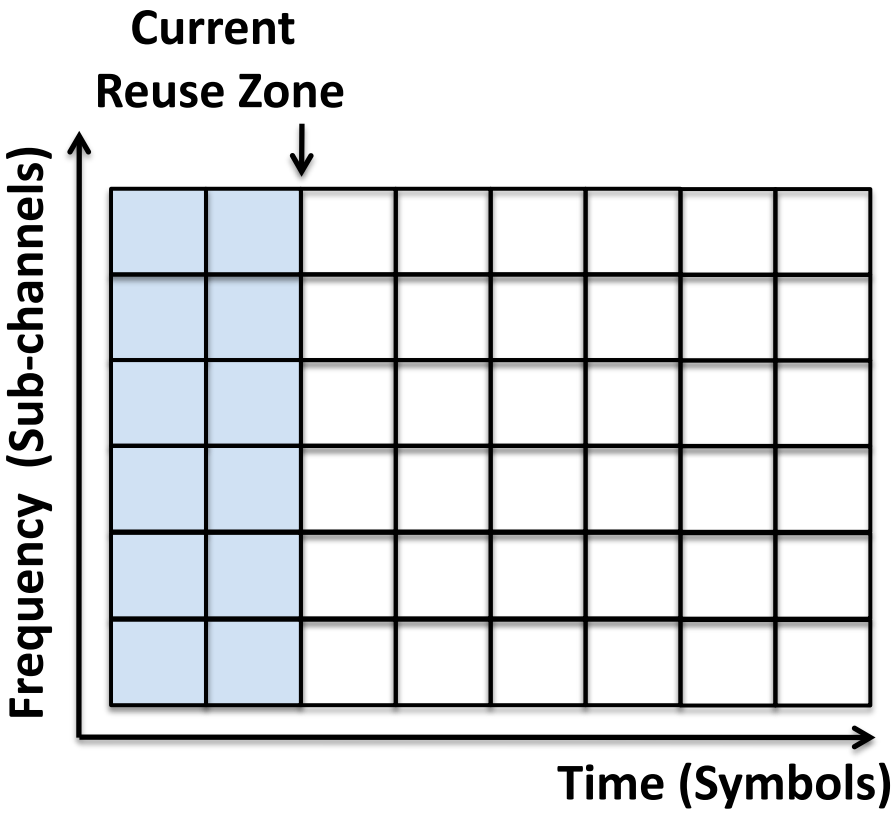
Joint probing

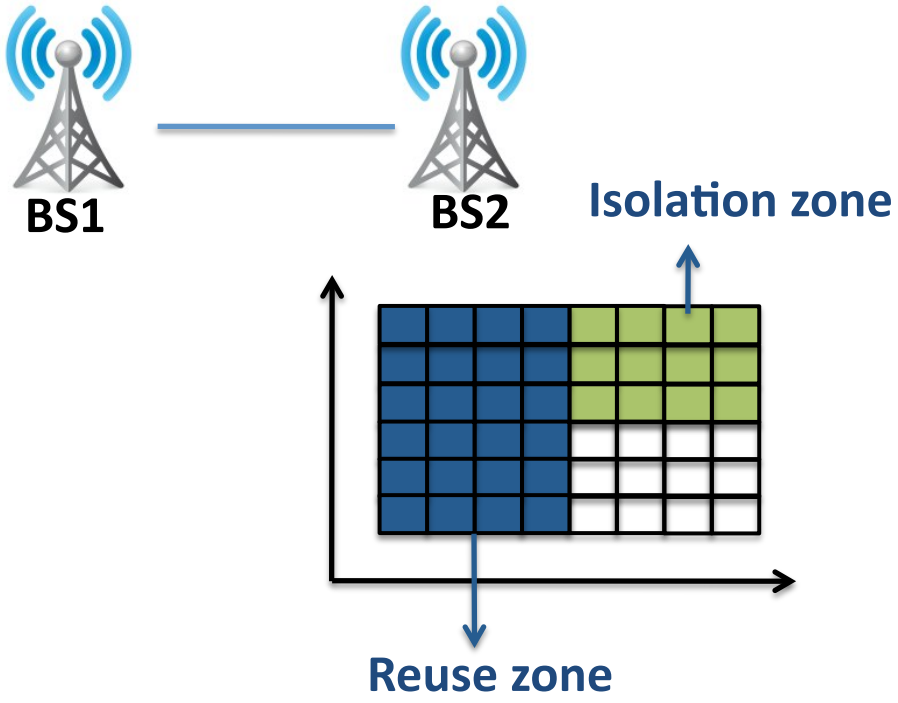
- Joint probing in 'Time' and 'Frequency' resources
  - Time probing: Finds the 1) common reuse zone and determines the 2) transition zone size
  - Frequency probing: Finds the 3) subset of sub-channels for resource isolation

Algorithm

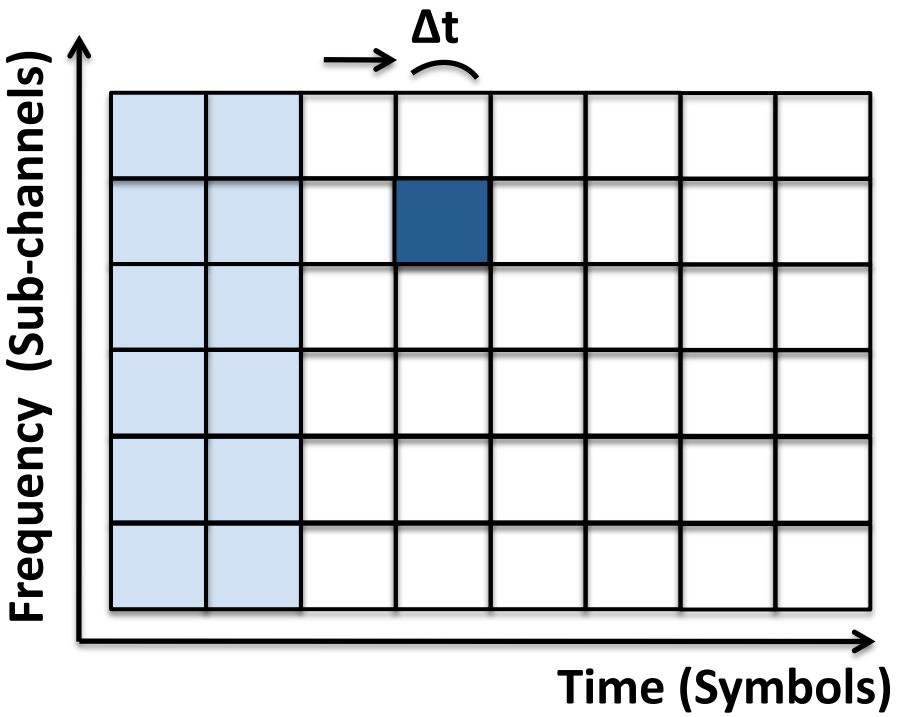
- Two-phase Adaptation
  - Coarse adaptation:
    - Period of 'P' frames, order of several seconds
    - Find the common reuse zone and frequency resources
  - Fine adaptation:
    - Every 'q' frames, hundreds of milliseconds
    - Repeated till convergence (confirmation)

Probing

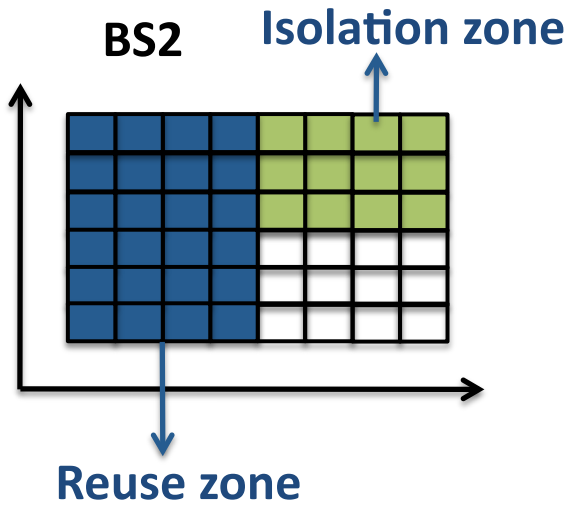

Current
Reuse Zone
Frequency (Sub-channels)
Time (Symbols)


BS1
BS2
Isolation zone
Reuse zone

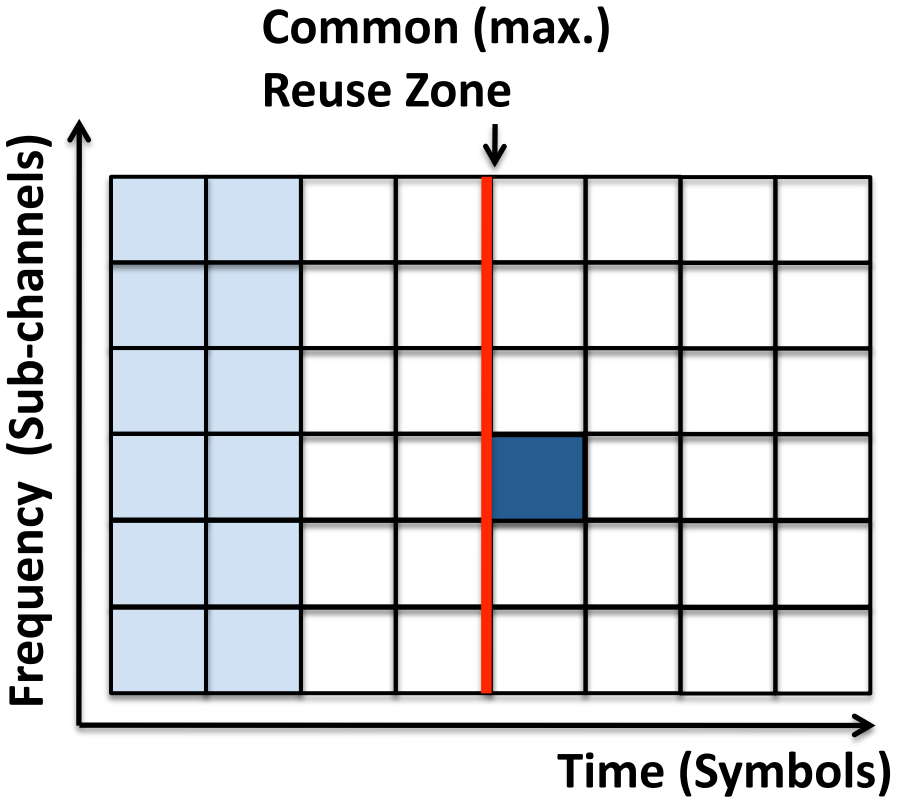
Probing



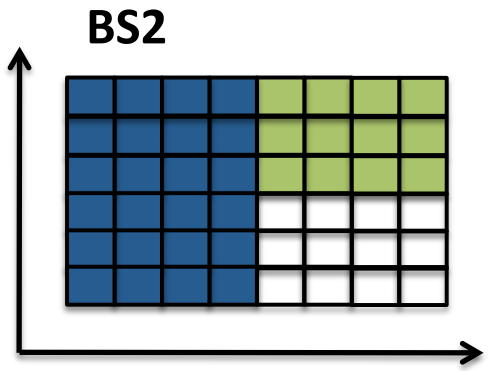
1. Coarse adaptation
   a. select probing resources (Δt)
   b. probe 'n' chunks and find the
      unused chunk
      if found; time converged
      else; repeat 1.a



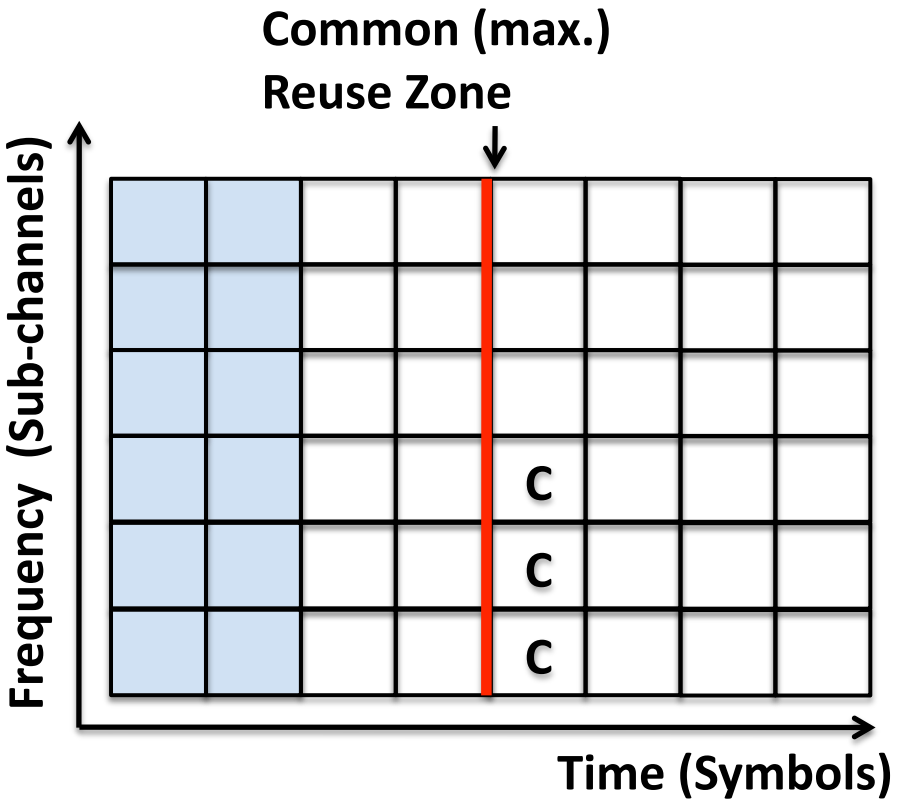
Probing



1. Coarse adaptation
   a. select probing resources (Δt)
   b. probe 'n' chunks and find the
      unused chunk
      if found; time converged
      else; repeat 1.a
   c. select frequency chunks (c)



Probing



1. Coarse adaptation
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      unused chunk
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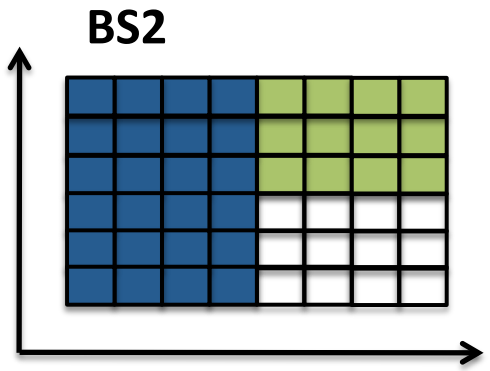
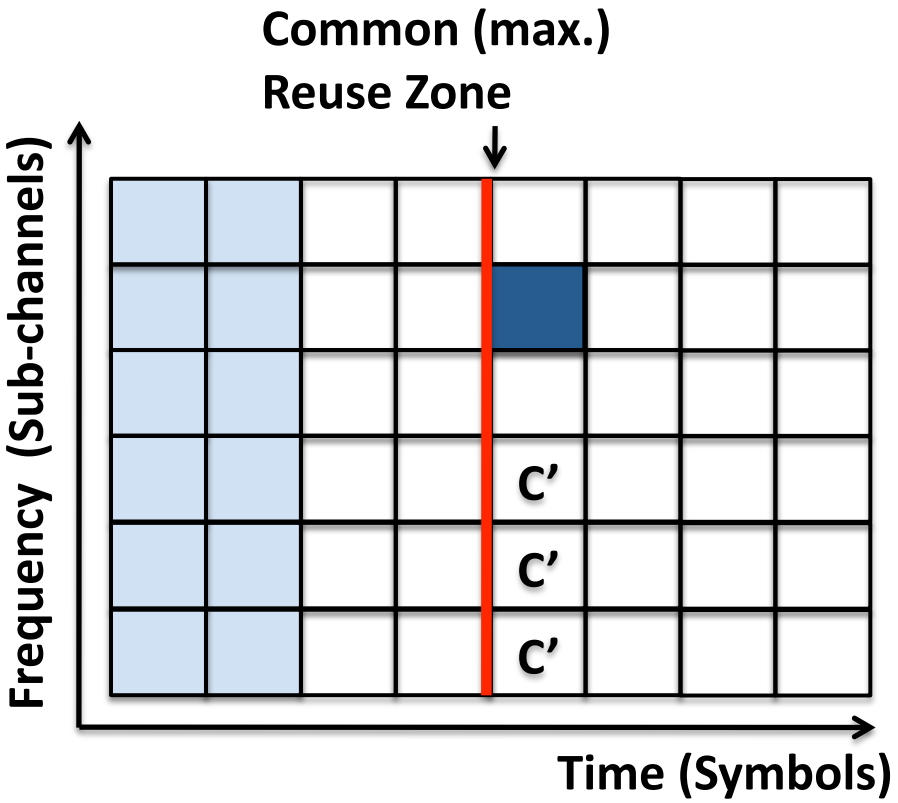


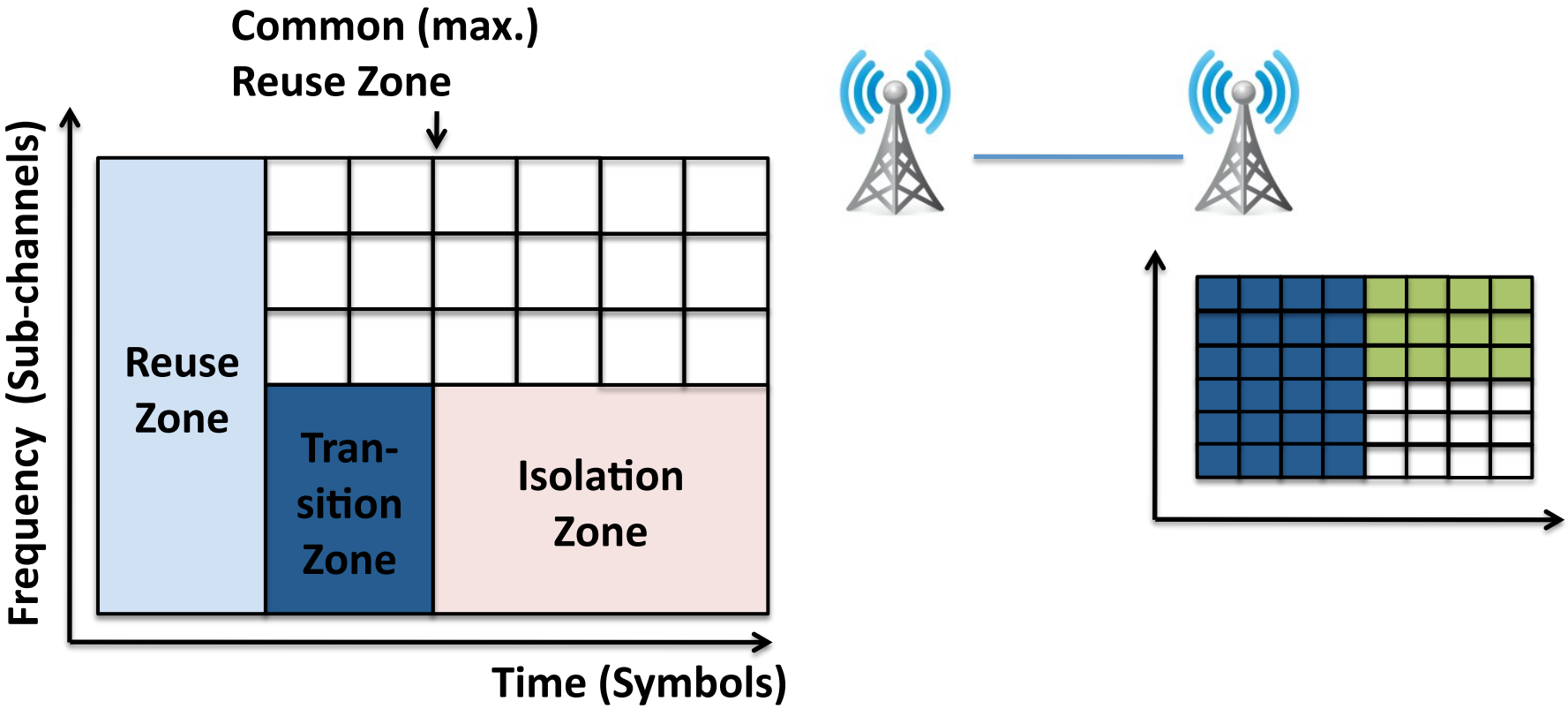
Probing



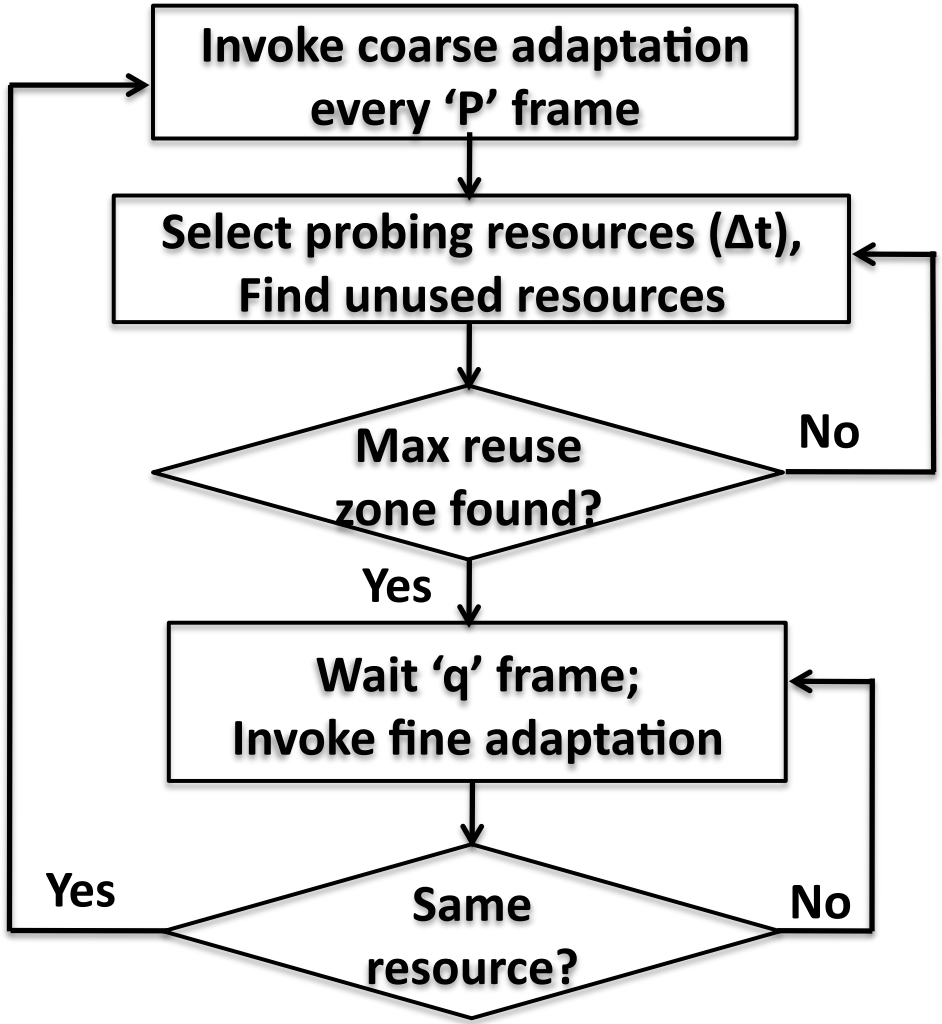
1. Coarse adaptation
   a. select probing resources (Δt)
   b. probe 'n' chunks and find the unused chunk
      if found; time converged
      else; repeat 1.a
   c. select frequency chunks (c)

2. Fine adaptation
   a. probe 'n' chunks and select frequency chunks (c')
   b. if c == c'; frequency converged
      else; repeat 2.a

Probing


Common (max.)
Reuse Zone
Frequency (Sub-channels)
Reuse Zone
Tran-
sition
Zone
Isolation
Zone
Time (Symbols)

Two-phase Adaptation

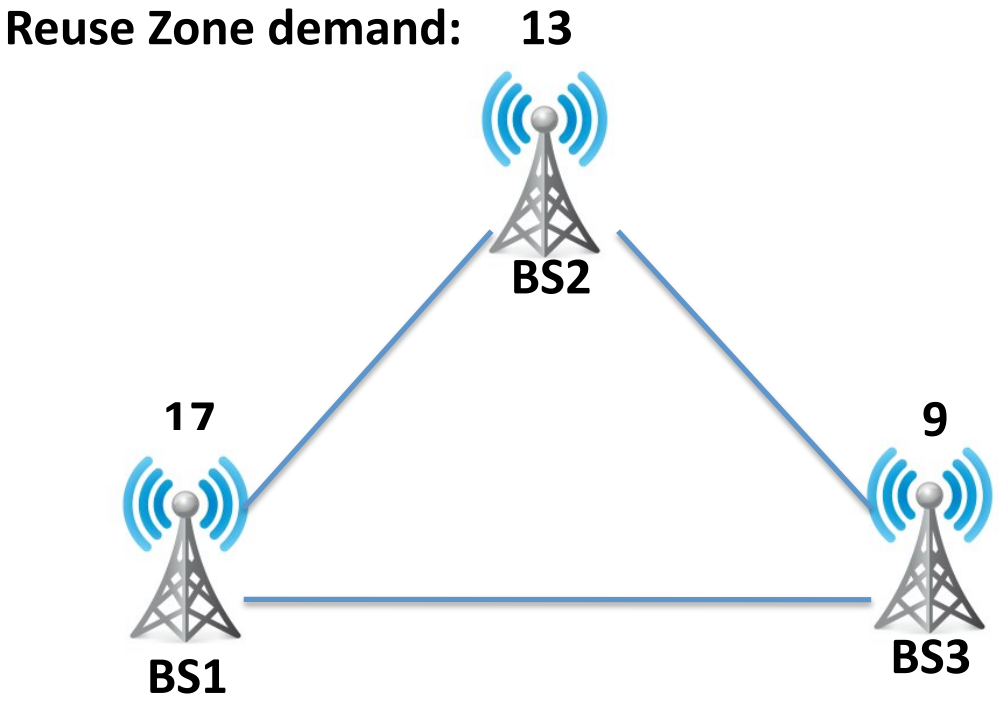


Challenges and solutions

1. Scheduling multiple clients in the same frame
   → Zoning (Reuse and Isolation zones)
2. Resource coupling across the femtocells
   → Transition zone
3. Distributed resource allocation framework
   → Two-phase adaptation algorithm

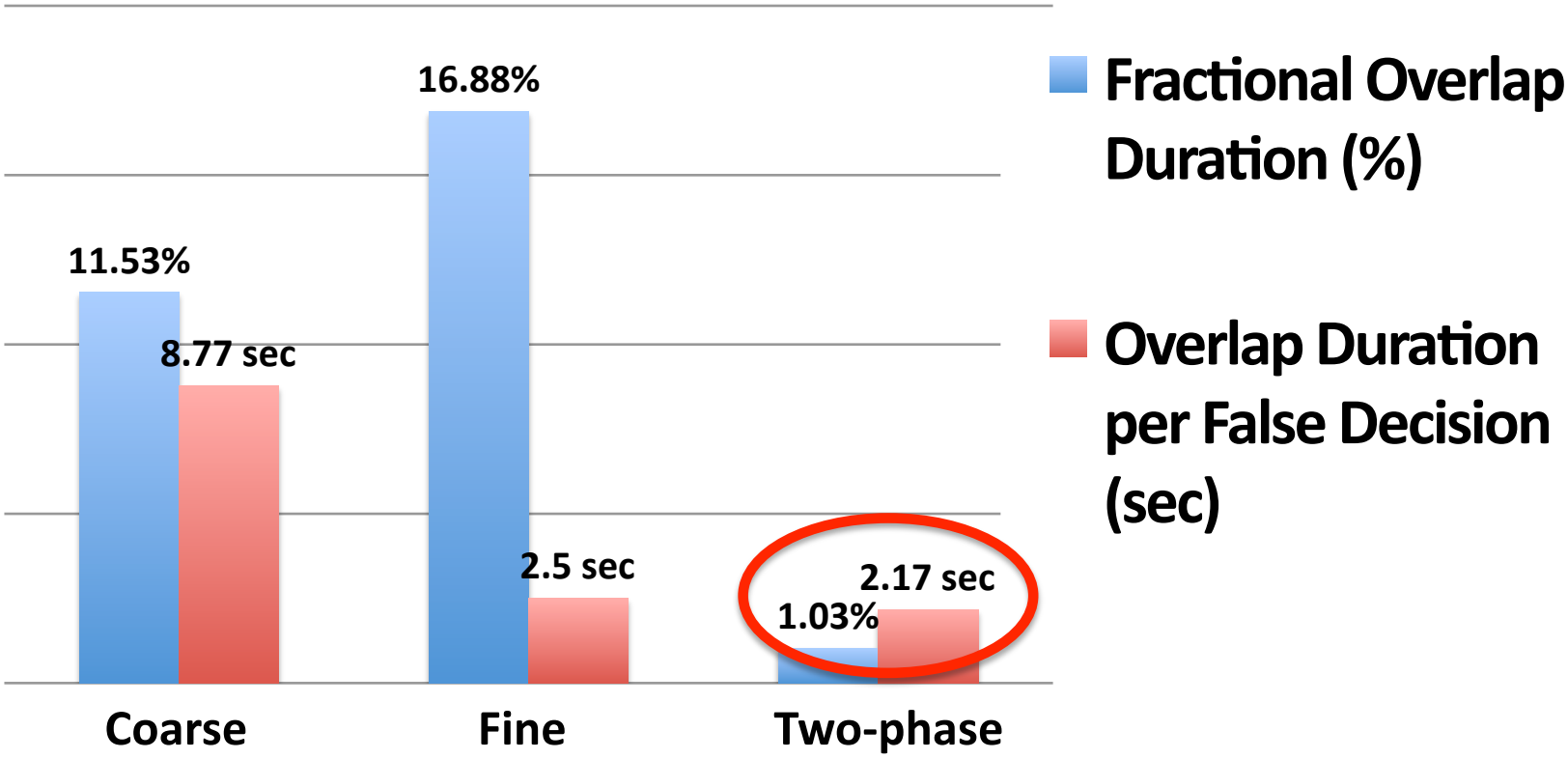
Evaluation

- Topology

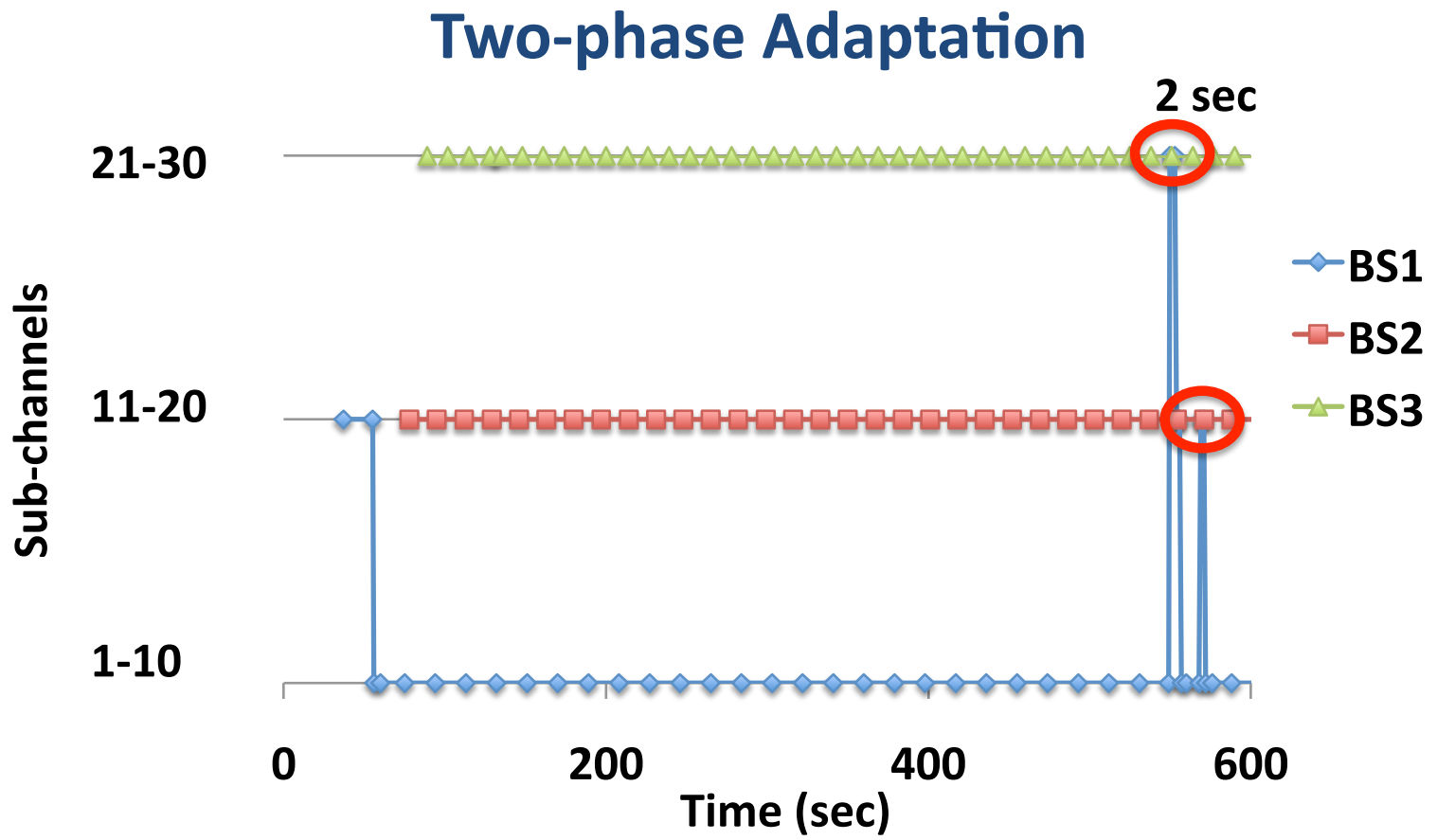


Evaluation

Overlapping duration



Frequency convergence pattern



Conclusion

- RADION: A self-organizing, distributed resource management framework for OFDMA femtocells.
  - Using three-zone frame structure to maximize the system utility while decoupling resources across the femtocells
  - Two-phase adaptation and resource allocation
  - Each cell determines the size of the reuse, transition and isolation zones without coordination.
- Implemented using a WiMAX testbed with commercial clients.

Thank You!

- Questions?