

17. FFV-Workshop 2010

Frequency Reuse Techniques for Attaining both Coverage and High System Capacity in OFDMA Cellular Systems

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- **Introduction**
- **Soft Frequency Reuse (SFR)**
- **Incremental Frequency Reuse (IFR)**
- **Enhanced Fractional Frequency Reuse (EFR)**
- **Performance Evaluation**
- **Conclusion**

Resource Reuse to enhance system capacity

- **Classical frequency reuse factor 1**
 - ✗ Heavy inter-cell interference (ICI), especially near cell edge
 - ✗ inferior area coverage
 - ✗ lower cell capacity
 - ✓ High spectrum usage
- **Conventional frequency reuse factor 3 or 7**
 - ✓ Reduced inter-cell interference (ICI)
 - ✓ Better cell coverage
 - ✗ Lower system spectrum efficiency
 - ✗ Low cell capacity
- ***Highly desirable of interference limited system while retaining system spectrum efficiency of reuse 1***

Frequency Reuse Techniques

Contents – **Introduction** – SFR – IFR – EFR – Performance Evaluation – Conclusion

Most promising approaches

- **Soft Frequency Reuse (SFR) Scheme**

 - Adopted in the 3GPP-LTE system
 - Overcome severe ICI for cell edge users by increasing
 - Frequency reuse factor
 - Transmission power

- **Incremental Frequency Reuse (IFR) Scheme**

 - Ki Tae Kim, 2008
 - ICI avoidance for low loading traffic

- **Enhanced Fractional Frequency Reuse (EFR) scheme**

 - ComNets
 - Enhancement design based on IFR & SFR



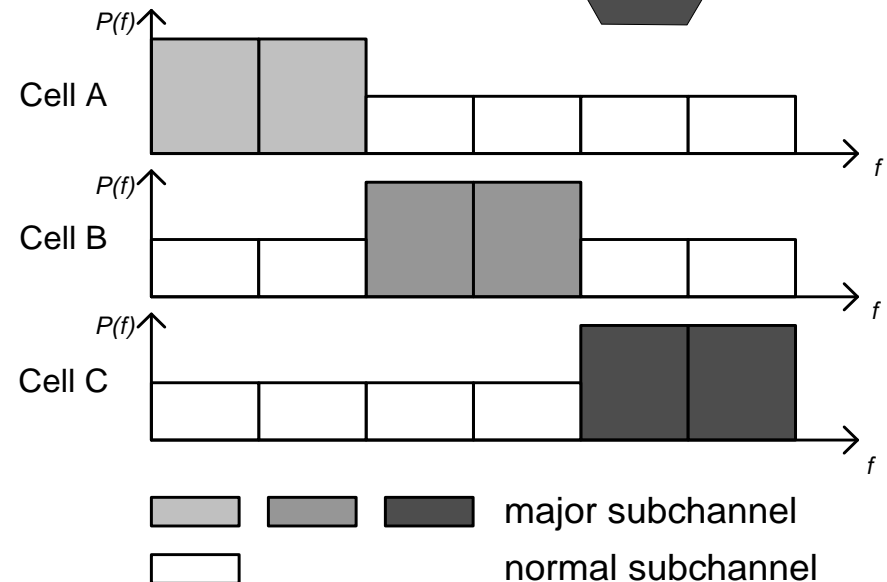
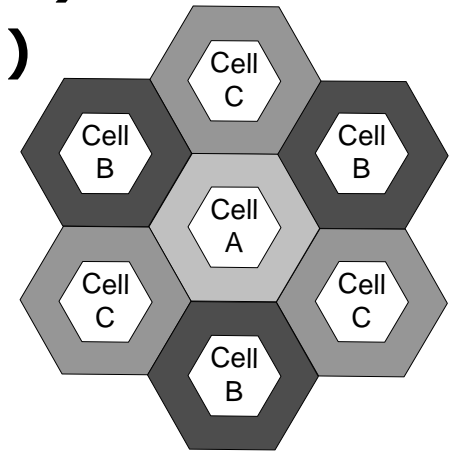
Soft Frequency Reuse (1/2)

Contents – Introduction – **SFR** – IFR – EFR – Performance Evaluation – Conclusion

✚ **Reuse factor 1 → cell-center users (CCU)**

✚ **Reuse factor 3 → cell-edge users (CEU)**

- CEU
 - 1/3 bandwidth: Major Segment
 - Higher power
- CCU
 - Whole bandwidth
 - Lower power



Benefits

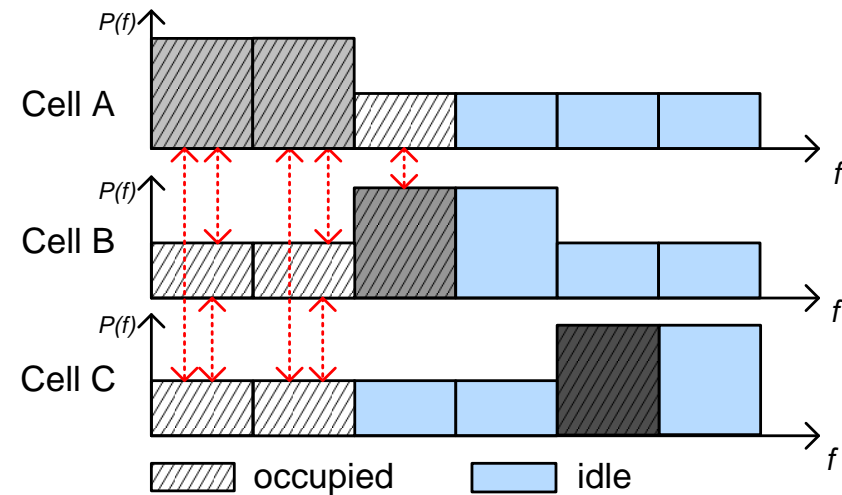
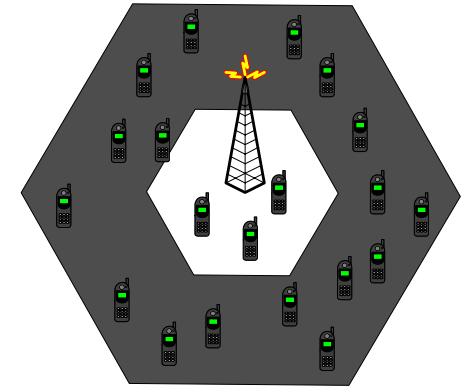
- ICI mitigation at cell edge
- Improved bit rate at cell edge
- Improvement of cell coverage & capacity

Soft Frequency Reuse (2/2)

Contents – Introduction – **SFR** – IFR – EFR – Performance Evaluation – Conclusion

Limitations

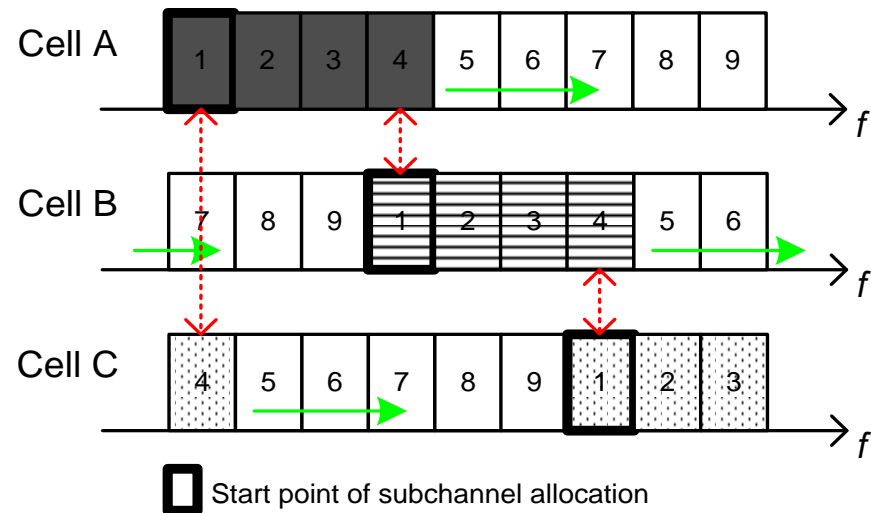
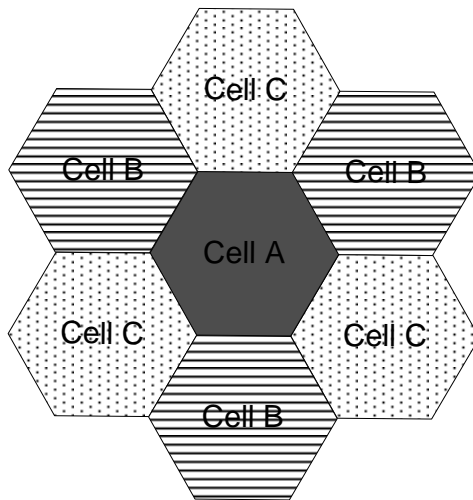
1. *Key issue*: zone definition for CCUs and CEUs
2. Low spectrum reuse efficiency
 - More CEUs, less CCUs
 - Less available resource for CEUs, whereas more for CCUs
3. More co-channel interferences even at low loading traffic situation
4. CEUs still grievously interfered by co-users in the neighboring cells
 - *Inclusive* reuse for CEUs



Incremental Frequency Reuse

Contents – Introduction – SFR – **IFR** – EFR – Performance Evaluation – Conclusion

- ✚ **Frequency reuse factor 1**
- ✚ **Different start point of subchannel assignment in neighboring cells → static**



Benefits

- Part of the limitations by applying SFR eliminated
- Effective ICI avoidance with low offered traffic

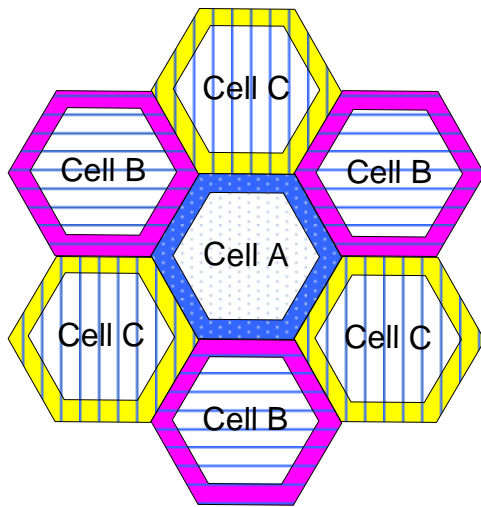
Limitations





- *Not better* than the classical reuse-1 system in full-load situation

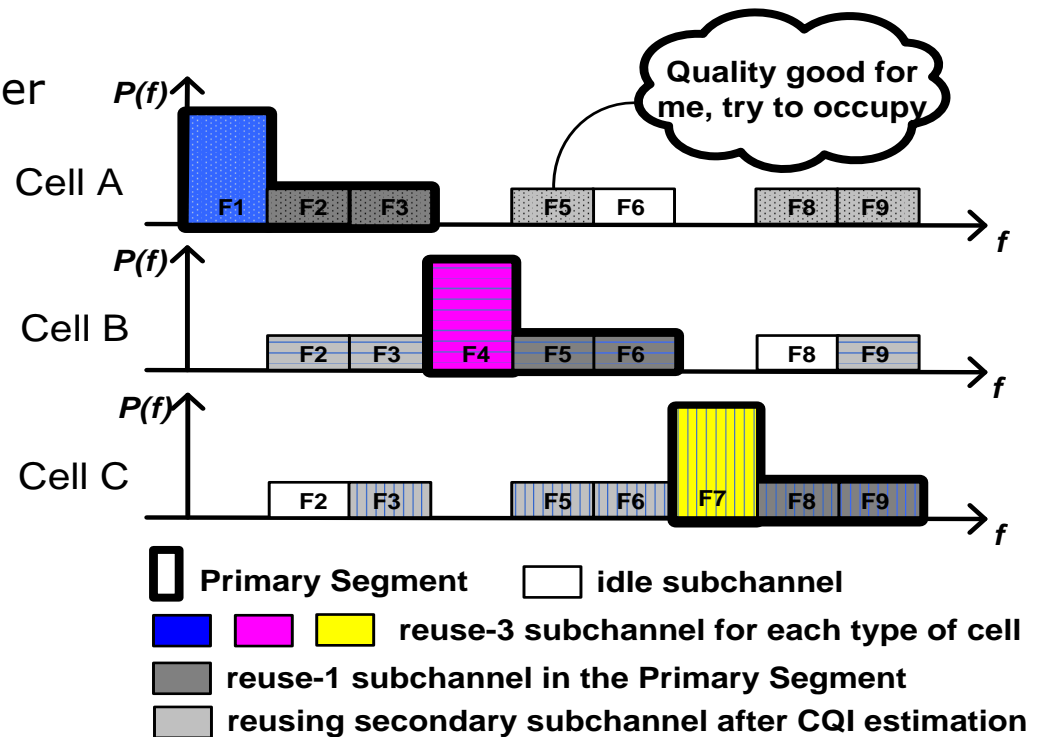
Enhanced Fractional Frequency Reuse (1/2)

Contents – Introduction – SFR – IFR – **EFFR** – Performance Evaluation – Conclusion

- ✚ **Entire frequency spectrum divided into 2 segments**
 - Primary Segment: orthogonal among neighboring cells
 - Secondary Segment
- ✚ **Exclusive reuse-3 subchannels in Primary Segment**
 - $Priority_{CEU} > Priority_{CCU}$
 - Higher transmission power
- ✚ **Reuse-1 subchannels**
 - Lower transmission power



 $F_{SUM} - F1 - F4 - F7$
 F1  F4  F7

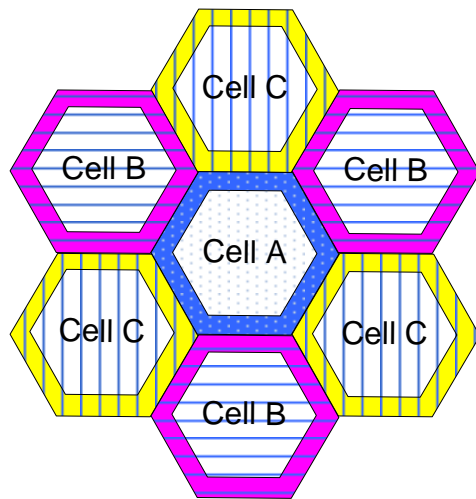


Enhanced Fractional Frequency Reuse (2/2)

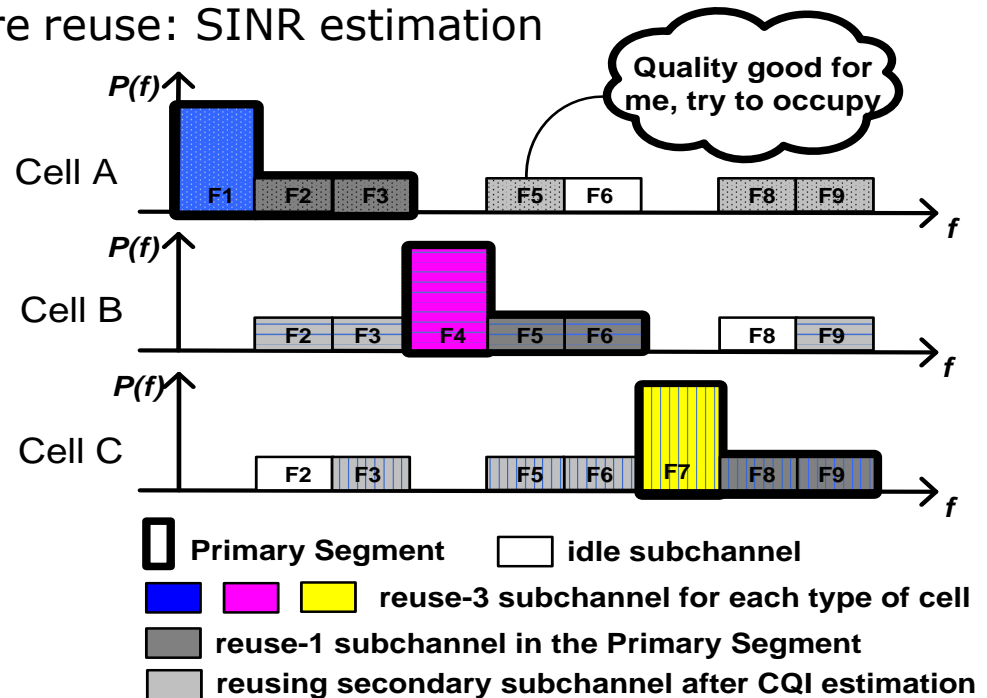
Contents – Introduction – SFR – IFR – **EFFR** – Performance Evaluation – Conclusion

Resource allocation

1. Primary Segment occupation
 - CEUs → reuse-3 subchannels
 - CCUs → reuse-1 subchannels
2. Secondary Segment occupation
 - Monitor before use
 - Interference-aware reuse: SINR estimation



○ $F_{SUM} - F1 - F4 - F7$
■ F1 ■ F4 ■ F7



Scenario

Contents – Introduction – SFR – IFR – EFFR – **Performance Evaluation** – Conclusion

- Implementation of SFR, IFR & EFFR in OpenWNS simulation environment
- EFFR with three M to N combinations
 - **M** : number of reuse-3 subchannels in Primary Segment
 - **N** : number of reuse-1 subchannels in Primary Segment
- Scenarios with surrounding cells up to 2nd-tier
- Constant total system transmission power assumption
 - Max. transmission power of UT: 23dBm
 - SFR & EFFR: $\alpha = P_{High} / P_{Low} = 3$
- UL considered
- UTs uniformly distributed in each cell

Mean cell capacity with 25 users in each cell

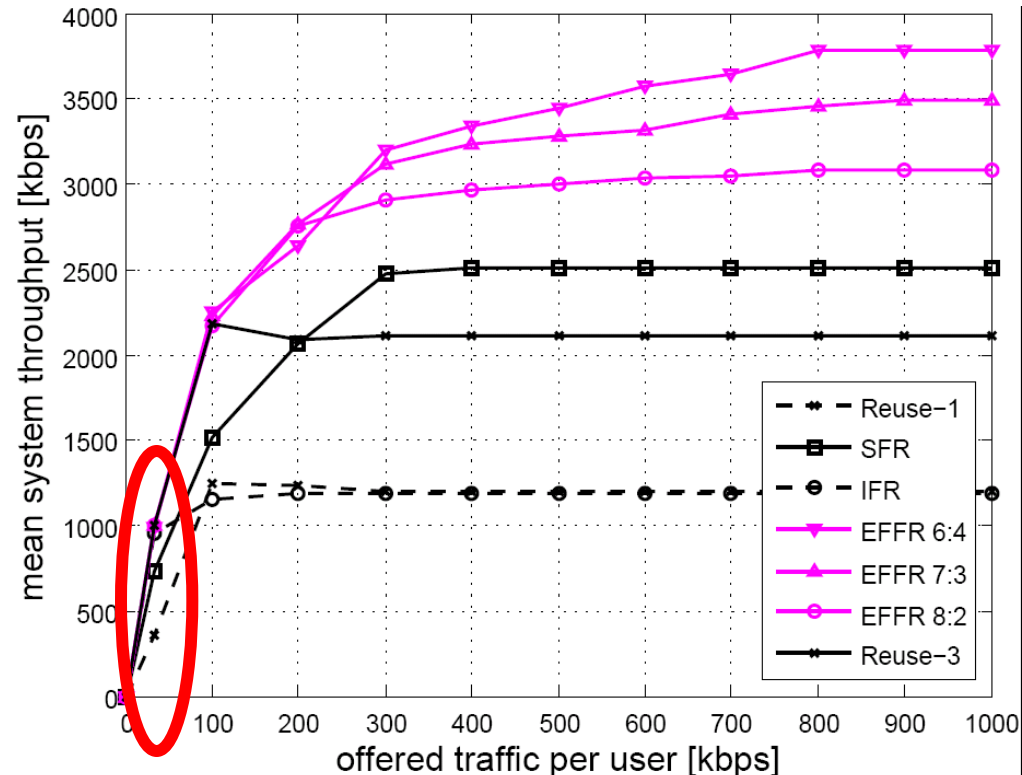
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Simulation parameter

System bandwidth: 20 MHz
Center frequency: 5470 MHz
Subcarriers (FFT size): 2048
Subchannels: 30
OFDMA symbol duration: 102.858 μ s
Frame length: 10 ms
DL : UL-ratio: 1:1
Cell radius: 1100m
Path loss exponent: 2.9
Interfering cells: 18
(up to 2 tiers)
Traffic model: symmetric,
neg. exp IAT

- Increasing offered traffic per use

$$- r/R = \frac{Radius_{CCU}}{Cell_Radius} = 0.5$$

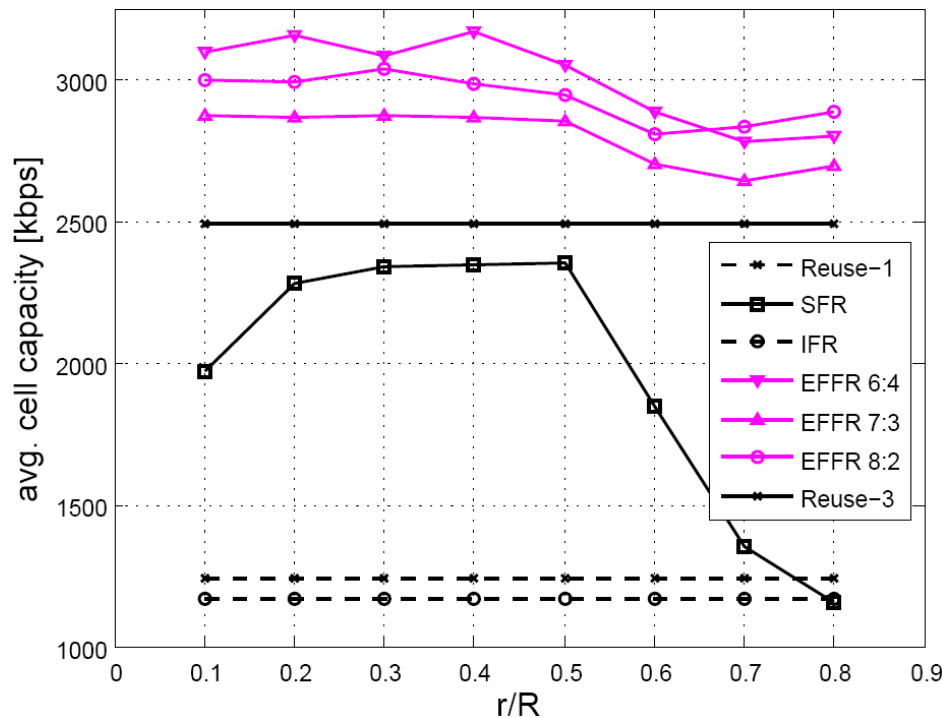


Mean throughput with 15 users in each cell

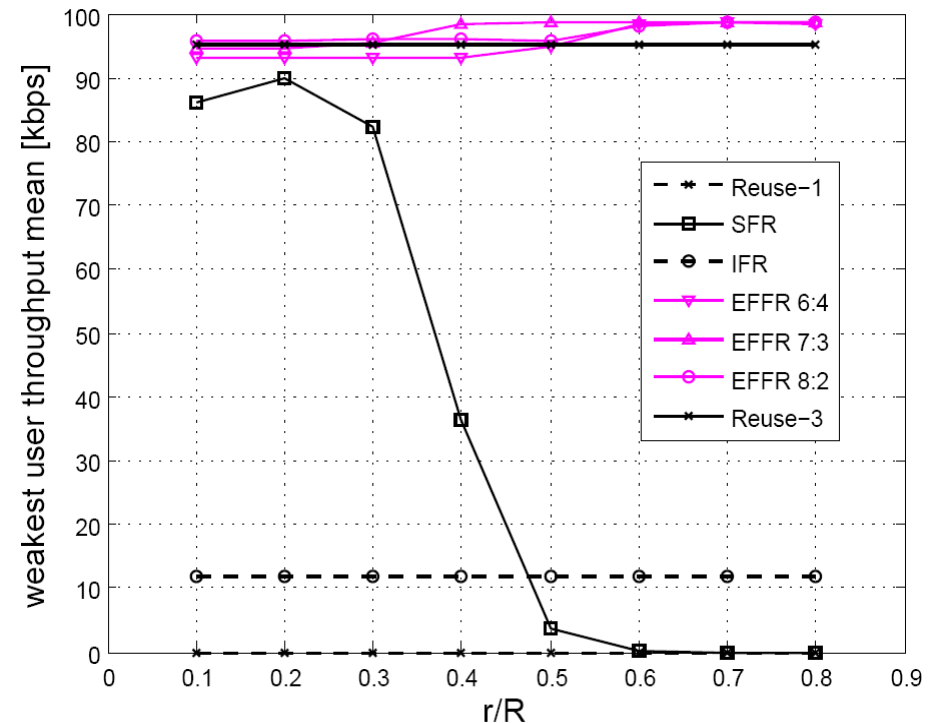
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- 333 kbps offered traffic per user
- Zone for weakest users: 900m – 1100

- Mean overall cell capacity



- Mean weakest user throughput → Coverage



Conclusion

- For wide area coverage & high system capacity
 - SFR & IFR overview
 - Design of an EFR scheme for ICI mitigation & implementation in OpenWNS
 - Exclusive reuse partitioning
 - Power allocation
 - Interference-aware reuse mechanism
- Theses: EFR achieves
 - Effective ICI limitation at cell edge
 - Effective ICI avoidance with low offered traffic
 - Substantial improvements in terms of both overall cell capacity & the cell coverage

Thank you for your attention !

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Any questions?

Scenario

Contents – Introduction – SFR – IFR – EFR – **Performance Evaluation** – Conclusion

- Implementation of SFR, IFR & EFR in OpenWNS simulation environment
- EFR with three M to N combinations
 - M : number of reuse-3 subchannels in Primary Segment
 - N : number of reuse-1 subchannels in Primary Segment
- Constant total system transmission power assumption
 - Max. transmission power of UT: 200mW
- Scenario with surrounding cells up to 2nd-tier
- UL considered

