Performance Evaluation of a Coordinated Time-Domain eICIC Framework based on ABSF in Heterogeneous LTE-Advanced Networks

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IEEE Globecom
December 2012
Agenda

- The ABSF Mechanism.
- The Proposed ABSF Framework.
  - Tracking of MUEs to Mark and Unmark Victim State.
  - ABSF-mode Triggering at Aggressor HeNBs.
  - Coordination Scheme between HetNet Nodes.
  - Enhancements of the Scheduling Scheme.
  - Estimation of SINR during ABSF using Kalman Filter
- Performance Evaluation.
- Conclusions and Future Trends.
The ABSF Mechanism
Multi-Tier HetNet Environment

Core Network

Backhaul

Internet

Macro

Femto

MUE

HUE

Pico

PUE
eICIC Framework

- eICIC
  - Time-Domain
  - Power Control
  - Frequency-Domain
ABSF Technique

- Almost Blank SubFrame

Figure from 3GPP TSG RAN WG1, R1-104661, “Comparison of Time-domain eICIC Solutions”
ABSF Technique

- Almost Blank SubFrame

Figure from 3GPP TSG RAN WG1, R1-103264, “Performance of eICIC with Control Channel Coverage Limitation”
ABSF Patterns (FDD mode)

- 1/8 Pattern
- 2/8 Pattern
- 3/8 Pattern
- 3/20 Pattern
The Proposed ABSF Framework
The Proposed ABSF Framework

- VMUEs Tracking
- Aggressor HeNBs Identification
- Prioritized Scheduling
- SINR Tracking during ABSF (Kalman Filter)
- HetNet Nodes Coordination

ABSF Framework
Tracking of MUEs
Tracking Procedure

MeNB filters the received CQI feedbacks based on:

\[ CQI_f[n] = [\alpha \cdot CQI[n] + (1 - \alpha) \cdot CQI_f[n - 1]] \]

where:
- \( CQI_f[n] \) The filtered CQI at time instant \( n \)
- \( CQI[n] \) The CQI feedback at time \( n \)
- \( \alpha \) The filter coefficient (\( \alpha = 0.2 \))

If \( CQI_f[n_{start} + 50 \text{ ms}] \leq 3 \) Then
Selection of Aggressor HeNBs

\[ \text{SINR}_{MUE} = \frac{P_{MUE}}{\sum P_{\text{HeNBs}} + \sum P_{\text{MeNBs}} + N} \]

Activate as many aggressor HeNBs until the SINR of the VMUE reaches certain predefined target SINR.

RSRP Measurement Report

- HeNB PCI 1 : -65 dB
- HeNB PCI 2 : -76 dB
- HeNB PCI 3 : -70 dB
- HeNB PCI 4 : -92 dB
- HeNB PCI 5 : -85 dB
- HeNB PCI 6 : -53 dB
Trigger ABSF-mode at HeNBs

Trigger ABSF mode
Pattern: 1/8
The coordination scheme between the HetNet nodes is based upon 3 control messages:

- CQI feedbacks (*Already in place*)
- RSRP Measurement Report (*Already in place*)
- ABSF-mode Trigger Control Message (*new*)
Enhancement of the Scheduling Strategy

$$m_{i,j} = \beta \cdot m_{i,j}$$

- $m_{i,j}$: scheduling metric to assign channel $j$ to user $i$
- $\beta$: a factor to scale the scheduling metric to:
  - Prohibit VMUEs from being scheduled in non ABSFs ($\beta = 0$)
  - Gives higher priority for VMUEs to be scheduled in ABSFs ($\beta = 10$)
Tracking of SINR during ABSF

- SINR level during normal and ABSF subframes

Figure from the paper “eICIC Functionality and Performance for LTE HetNet Co-Channel Deployments”
Kalman Filter

Time Update ("Predict")

1. Project the state ahead
\[ \hat{x}_k^- = \hat{x}_{k-1} \]
2. Project the error covariance ahead
\[ P_k^- = P_{k-1} + Q \]

Initial estimates for \( \hat{x}_{k-1} \) and \( P_{k-1} \)

Measurement Update ("Correct")

1. Compute the Kalman gain
\[ K_k = P_k^- (P_k^- + R)^{-1} \]
2. Update estimate with measurement \( z_k \)
\[ \hat{x}_k = \hat{x}_k^- + K_k (z_k - \hat{x}_k^-) \]
3. Update the error covariance
\[ P_k = (1 - K_k) P_k^- \]
Performance Evaluation
## System Scenario

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>HetNet in LTE-Advanced, deployment centered at 2000 MHz, with a carrier bandwidth = 5 MHz</td>
</tr>
<tr>
<td>Macro-cell</td>
<td>Cell with a radius of 500 m, and ~0.65 km(^2) cell area, the eNB is centered in the cell area with omni antenna</td>
</tr>
<tr>
<td>Femto-cells</td>
<td>40 CSG femto-cells in 20 buildings uniformly distributed in the cell area with a density of ~60 femto-cell/km(^2). Each femto-cell is serving one HUE and fully loaded, and therefore utilize all subcarriers.</td>
</tr>
<tr>
<td>Frequency Reuse</td>
<td>3</td>
</tr>
<tr>
<td>Duplex Technique</td>
<td>FDD</td>
</tr>
<tr>
<td>Scheduling Scheme</td>
<td>Proportional Fair</td>
</tr>
<tr>
<td>Macro-cell Subscribers</td>
<td>10 MUEs uniformly distributed in the cell area with a CBR application, the CBR application has a varying rate from 50 kbps to 700 kbps for each MUE.</td>
</tr>
<tr>
<td>Femto-cell Subscribers</td>
<td>1 stationary HUE for each femto-cell, with CBR application of a rate 7 Mbps.</td>
</tr>
<tr>
<td>ABSF pattern</td>
<td>1/8</td>
</tr>
<tr>
<td>Simulation Aspects</td>
<td>Simulation time 100 secs, with 10 different realizations.</td>
</tr>
</tbody>
</table>

- We use the LTE-Sim open source simulator from the Politecnico di Bari
Aggregate Throughput of MeNB

- **Aggregate Throughput of the macrocell (Kbps)**
- **Input load of the macrocell (Mbps)**

- **ABSF mode**
- **Normal mode**

Graph showing the comparison between ABSF mode and Normal mode for aggregate throughput against input load of the macrocell.
Aggregate Throughput of VMUEs

Corrected Fig. 4 in the paper.
Aggregate Throughput of HeNBs

Input load of the macrocell (Mbps)

Aggregate throughput of the femtocells (Mbps)

- **ABSF mode**
- **Normal mode**
SINR During ABSF and Non-ABSF
The tracking of SINR during ABSF using Kalman filter

Measured SINR
Estimated SINR

SINR (dB.)

ABSF index
A comprehensive ABSF framework is proposed to cover the aspects concerning the deployment of ABSF technique in LTE-Advanced HetNet environments.

The framework uses existing control messages (CQI feedbacks and RSRP reports) and proposes a new control message (ABSF mode triggering).

Novel procedures and techniques are proposed:
- To track the MUEs and maintain their victim state.
- To ease the coordination between network nodes (MeNB, MUEs, and HeNBs).
- To enhance the scheduling scheme.
- To estimate the SINR level of the VMUEs during ABSF.
Future Work

✓ Formulation of the ABSF pattern selection problem.

✓ Performance evaluation of ABSF offsetting to enhance performance of unbalanced cell loading.

✓ Formulation of “Silence-Whisper” scheme as a mix between ABSF and power control schemes.
Questions & Discussions