Chapter 9:
A Green Handover Protocol in Two-Tier OFDMA Macrocell-Femtocell Networks

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Outline

- Abstract
- Introduction
- Related work
- Preliminaries and basic idea
- A green handover protocol
- Performance analysis
- Simulation results
- Conclusions
Abstract

- Most of the power consumption of the telecommunication networks is caused by the base stations. It is important to reduce the power consumption of the base stations for the green ICT (Information and Communication Technology).

- A handover is called as a green handover if the handover is an energy-saving handover with the minimized power consumptions of base station and the UE during the handover period. The base station switches off its hardware modules for the power-saving if no active user is resident in the coverage of base station.

- In this paper, we develop a green handover protocol in two-tier OFDMA macrocell-femtocell networks based on the remainder data of a mobile host can be completely uploaded through the “will-be-wake-up” femtocell base station.
1. Introduction

- Over 90% of the power in mobile communications is consumed by base station in the radio access network.

- According to the prediction of ABI (Allied Business Intelligence) research, more than 36 million femtocells are expectedly deployed around the world by the end of 2012. Assumed that each femtocell requires a power cost of 12W, the total energy consumption of all deployed femtocells amount to $3.784 \times 10^9$ kWh/annum.
The LTE/LTE-advanced and WiMax have been developed to redefine the traditional physical-layer air interface to bring the high transmission rate. With the emerging technology; such as Orthogonal Frequency Division Multiple Access (OFDMA).

In the LTE/LTE-advanced system, the total spectrum is partitioned into several pieces of spectrum which is denoted as “resource block (RB)” or “tile”. The sub-band is called as sub-channel in the WiMAX system.
A hierarchical radio access network which is a two-tier macrocell/femtocell network. The macrocell base station refers to MBS and the femtocell base station refers to FBS in the two-tier cellular networks.
The features of femtocell:

- low power
- low cost
- user-deployed
- small coverage range (e.g. 30 ~ 50 meters in diameter)

Ref: Femtocell Access Control Strategy in UMTS and LTE (IEEE MCOM 2009)
Channel operation

(a) Dedicated channel operation.

(b) Co-channel operation.

Ref: On Resource Reuse for Cellular Networks with Femto- and Macrocell Coexistence (IEEE Globecom 2010)
2. Related work

- Energy based

- Signal strength based
2. Related work

- Velocity based
Motivation

2. Related work

<table>
<thead>
<tr>
<th></th>
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<th>Idle</th>
<th>Power saving</th>
</tr>
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<tr>
<td>Femtocell</td>
<td>10.2(W)</td>
<td>6(W)</td>
<td>4.2(W)</td>
</tr>
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<td></td>
<td></td>
</tr>
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<td>≈ 0.2(W)</td>
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Ref: Energy and Cost Impacts of Relay and Femtocell deployment in LTE-Advanced (IET Communications 2011), 3GPP TS 36.101

Department of Computer Science and Information Engineering, NTPU
Motivation

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Comparison with existing protocol (WCNC 2010)

2. Related work

Ref: Improving Energy Efficiency of Femtocell Base Stations via User Activity Detection (IEEE WCNC 2010)
Comparison with existing protocol (WCNC 2010)

2. Related work

Total power consumption for femtocells

- FBS1: 6 (W)
- FBS2: 10.2 (W)

Proposed scheme
Objective

- The overall system power consumption of the two-tier macrocell-femtocell network, is minimized by intelligently switching on/off its radio communication and associated processing, which aims to keep the femtocell at the IDLE mode as far as possible,
- A handover decision protocol is designed to reduce the handover number and the signaling cost during the UE mobility.
System model

3. Preliminaries

Internet
P-GW
MME1/S-GW1
ASN-GW1
CN
MME2/S-GW2
ASN-GW2
Core Network
F-GW
FBS1, FBS2, FBS3, FBS4, FBS5, FBS6
MBS1 spectrum band
MBS1
MBS2 spectrum band
MBS2
FBS1, FBS2, FBS3, FBS4, FBS5, FBS6
UE

MBS: Macro base station
FBS: Femto base station
LTE
P-GW: Packet data network gateway
S-GW: Serving gateway
MME: Mobility management entity
WiMAX
ASN-GW: Access service network gateway
CSN: Connectivity service network
Femtocell hardware

(a) ACTIVE mode

(b) IDLE mode

Total power consumption: 10.2W

Total power consumption: 6W

Ref: Improving Energy Efficiency of Femtocell Base Stations via User Activity Detection (IEEE WCNC 2010)
It is observed that a FBS switches from IDLE mode into ACTIVE mode only if $t_{\text{dwell}} \geq t_{\text{expected}}$

But if, $t_{\text{dwell}} < t_{\text{expected}}$, then the FBS should not be wake up from the IDLE mode, and the UE still connects with the macro BS and do not perform the handover procedure.
A new green handover procedure is developed to minimize the power consumption of femtocells and the handover cost. The contribution of this paper is

- The overall system power consumption of the two-tier macrocell-femtocell network, is minimized by intelligently switching on/off its radio communication and associated processing.
- A handover decision protocol is designed to reduce the handover number and the signaling cost during the UE mobility.
A Green Handover Protocol in Two-Tier OFDMA Macrocell-Femtocell Networks
4. A green handover protocol

- The main function of the green handover protocol is to make an intelligent decision of accurately wake-up the FBS from IDLE mode into ACTIVE mode at the right time and at the right place. This is mainly based on the prediction of the dwell time and average expected transmission time of the UE.

- The developed protocol consists of three phases:
  - Free spectrum configuration phase
  - Transmission time estimation phase
  - Green handover decision phase
Free spectrum configuration phase

4. A green handover protocol
Free spectrum configuration phase

4. A green handover protocol
This phase is divided into three parts:

- The dwell time
- The required bandwidth
- The average expected transmission time

Shannon theorem:

\[ R = B \times \log_2 (1 + SNR) \]

Path loss model:

\[ PL = 38.46 + 20 \log_{10} d \]
4. A green handover protocol

\[ \theta_C = \theta_1 - \theta_0 \]

\[ \theta = \cos^{-1} \frac{d_{U1,F1}^2 + d_{t0-t1}^2 - d_{U1,F1}'^2}{2d_{U1,F1}d_{t0-t1}'} \]

\[ \alpha = \frac{\int_{d_{UE,FBS1}}^d SNR_{UE} - 38.46 + 20\log_{10}(d)}{t_1 - t_0} \]

\[ SNR_{MAX} = SNR_{UE} - (38.46 + 20\log_{10}(R\sin\theta)) \]

\[ t_{tp} = 2 \times \frac{SNR_{MAX}}{\alpha} \]

\[ t_{tp} - \Delta t = t_{tp} - (t_{i+1} - t_1) \]
An IDLE initially allocates \( l = 1 \) tile for the UE.

\[
E_{\text{UE}}^B(\phi) = E_{\text{C}}^{(\text{UE},1)}(\phi) = \delta
\]

- If \( l \neq 1 \), the effective capacity is

\[
E_{\text{C}}^{(\text{UE},l)}(\phi) = l\omega_l E_{\text{C}}^{(\text{UE},1)}(l\omega_l \phi)
\]

- The delay bound probability:

\[
Pr\{\text{Delay} > t_{\text{dwell}}\} = e^{-\phi\delta t_{\text{dwell}}}
\]

- If \( Pr\{\text{Delay} > t_{\text{dwell}}\} = e^{-\phi\delta t_{\text{dwell}}} > \varepsilon_{\text{UE}} \), then \( l \) is increased.

The average expected transmission time:

\[ t_{\text{expected}} = \frac{D_{\text{remainder}}}{R_{\text{UE}}} \]

The average transmission rate:

\[ R_{\text{average}}^{\text{UE}} = l_{\text{required}} \times \log_2 (1 + R_{\text{SSS}}^{\text{dB}}) \]

\[ R_{\text{SSS}}^{\text{dB}} = SN R_{\text{FBS}} - PL_{\text{average}}, \]

\[ PL_{\text{average}} = \frac{1}{2R} \int_{0}^{2R} 38.46 + 20 \log_{10}(d) \, d(d) \]
Green handover decision phase

4. A green handover protocol
Handover preparation

4. A green handover protocol

1. Received power measurement on UE uplink and remainder data of UE

2. Measurement control
   - packet data
   - UL allocation

3. Pilot power transmission, BCCH (CGI, TAI, CSG ID)

4. Measurement reports
   (CGI, TAI, CSG ID, Member Indication)

5. HO decision

6. (a) HO request

7. (b) HO request

7. (c) HO request

8. Admission Control

9. (a) HO request ack

9. (b) HO request ack

Legend
- L3 signalling
- L1/L2 signalling
- User Data

Handover preparation
Handover execution

4. A green handover protocol

10. Handover command
   - Detach from serving MBS and synchronize to FBS
   - Deliver buffered and in transit packet to FBS

11. (a) SN status transfer
    - Data forwarding
11. (b) SN status transfer
    - Data forwarding
11. (c) SN status transfer
    - Data forwarding

12. Synchronization

13. UL allocation + TA for UE

Buffer packets from MBS
Handover completion

4. A green handover protocol
5. Performance analysis

- **Lemma 1**: The average energy consumption for the data transmission of an UE during an in-bound mobility of Ashraf protocol is

\[
P(k, T) = \frac{(\lambda T)^k}{k!} e^{-\lambda T}
\]

\[
P(k, T_j) = P(0, T_j) = P_{nj} = e^{-\lambda_j T_j}
\]

\[
\begin{align*}
\lambda_j &= \frac{1}{t_j} \\
T_j \text{ is equal to } t_{tp}
\end{align*}
\]

\[
E_A = E + \frac{1}{n} \sum_{j=1}^{n} (e^{-\lambda_j T_j} \times E_{idle} + (1 - e^{-\lambda_j T_j}) \times E_{active}).
\]
5. Performance analysis

- **Lemma 2**: The average energy consumption of the data transmission of an UE during an in-bound mobility of our proposed protocol is

\[ P_{c_j}(0, t_{\text{dwell}_j}) = P_{c_j} = e^{-(\lambda_j t_{\text{dwell}_j})} \]

\[ E_C = E + \frac{1}{n} \sum_{j=1}^{n} \left( e^{-\lambda_j T_j} \times E_{\text{idle}} + (1 - e^{-\lambda_j T_j}) \times \left( e^{-\lambda_j t_{\text{dwell}_j}} \times E_{\text{idle}} + (1 - e^{-\lambda_j t_{\text{dwell}_j}}) \times E_{\text{active}} \right) \right) \]
5. Performance analysis

- **Theorem 1**: Based on the results of lemma 1 and lemma 2, the average energy consumption of our proposed protocol is smaller than that of Ashraf protocol, $E_G < E_A$, i.e.,

\[
E + \frac{1}{n} \sum_{j=1}^{n} \left( e^{-\lambda_j T_j} \times E_{idle} + (1 - e^{-\lambda_j T_j}) \times (e^{-\lambda_j t_{dwell_j}} \times E_{idle} + (1 - e^{-\lambda_j t_{dwell_j}}) \times E_{active}) \right) < 
\]

\[
E + \frac{1}{n} \sum_{j=1}^{n} \left( e^{-\lambda_j T_j} \times E_{idle} + (1 - e^{-\lambda_j T_j}) \times E_{active} \right)
\]
6. Simulation results

- **Simulation tool:**
  - NS-2 v2.28 + EURANE

- **Simulation environment**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Networks size</td>
<td>1000mX1000m</td>
</tr>
<tr>
<td>MBS transmission range</td>
<td>1000m</td>
</tr>
<tr>
<td>FBS transmission range</td>
<td>50m</td>
</tr>
<tr>
<td>Vehicle velocity</td>
<td>30 - 80 (km/hr)</td>
</tr>
<tr>
<td>Number of femtocells</td>
<td>6</td>
</tr>
<tr>
<td>Data size</td>
<td>10M - 15Mbytes</td>
</tr>
<tr>
<td>Packet size</td>
<td>1000bytes</td>
</tr>
<tr>
<td>Simulation time</td>
<td>20-40sec</td>
</tr>
</tbody>
</table>
The performance metrics

- **Power consumption of all FBSs**
  - The total power consumption of an UE and all FBSs.

- **Handover latency**
  - The total time duration that the previous packet data is sent from serving BS to target BS.

- **Packet loss**
  - The packet loss occurs when one or more packets of data traveling across a network fail to reach their destination.

- **Signaling cost of handover**
  - The number of exchange information with MBS or FBS in the handover procedure.
Power consumption vs. data size
Power consumption vs. velocity

6. Simulation results

- Green handover
- Green handover-A
- Ashraf protocol
Handover latency vs. data size

6. Simulation results

- Green protocol
- Ashraf protocol
Handover latency vs. velocity

6. Simulation results

![Graph showing handover latency vs. velocity for Green and Ashraf protocols. The x-axis represents velocity (m/s) ranging from 30 to 80, and the y-axis represents handover latency (ms) ranging from 100 to 450. The Green protocol is represented by red squares, and the Ashraf protocol is represented by blue triangles.](graph.png)
Packet loss ratio vs. data size

6. Simulation results
Packet loss ratio vs. velocity

- Green protocol
- Ashraf protocol

Simulation results
Signaling cost of handover vs. data size

6. Simulation results
Signaling cost of handover vs. velocity

6. Simulation results

![Graph showing the signaling cost of handover vs. velocity for Green and Ashraf protocols.](image-url)
7. Conclusions

- This paper presents a green handover protocol in two-tier OFDMA macrocell-femtocell networks. With the consideration of the velocity and power consumption, a green handover protocol is developed in two tier cellular environment.

- The simulation results reflect that the proposed green handover protocol significantly reduce the power consumption and the number of undesired handovers.