Adaptive Subcarrier Allocation Schemes for Wireless OFDMA Systems in WiMAX Networks

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IEEE Journal on Selected Areas in Communications (JSAC), Feb. 2009

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Outline

• Introduction
• System Model
• Adaptive Subchannel Allocation
  ▫ Fair Allocation
  ▫ Proportional Allocation
  ▫ Equal Capacity Increment Allocation
• Numerical Results
• Conclusion
• Summary
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Introduction

• **OFDMA**
  ▫ Provide a flexible multiuser access scheme
  ▫ Multiuser diversity
  ▫ Maximize the system capacity or maintain the desired system performance

• **Subcarrier allocation strategies can follow different criteria:**
  ▫ Fair
  ▫ Maximizing overall network throughput
  ▫ Depending on the network requirements
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System Model

- OFDMA system for mobile wireless MANs
- AMC Slot
  - A group of adjacent subcarriers
  - 2 bins (9 subcarriers) and 3 OFDM symbols
  - 48 data subcarriers and 6 pilot subcarriers
- 8ms frame duration
- 10MHz channel
- TDD structure
- 79 OFDM symbol per frame
- Adaptive modulation schemes
  - QPSK, 16-QAM, and 64-QAM
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• **Adaptive Subchannel Allocation**
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Fundamental Capacity function

- Channel capacity of a subcarrier (Shannon Capacity)
  \[ C_p = B_p \log_2 \left( 1 + \frac{E_s}{T_s N_0 B_p} \right) = B_p \log_2 \left( 1 + \frac{E_s}{N_0} \right) \]

- Capacity belonging to an OFDM symbol per frame
  \[ C_{p,\text{OFDM}} = \frac{1}{N_s} C_p = \frac{1}{N_s} B_p \log_2 \left( 1 + \frac{E_s}{N_0} \right) \]

- Capacity of an N*M rectangular slot
  \[ C_{\text{SLOT}} (\alpha_{\text{SLOT}}) = \frac{N \cdot M}{N_s} B_p \log_2 \left( 1 + \frac{E_s}{N_0} \alpha_{\text{SLOT}}^2 \right) \]

- \( B_p \): carrier spacing
- \( E_s \): symbol energy
- \( T_s \): symbol time
- \( N_0 \): noise for AWGN channel model
- \( N_s \): number of OFDM symbols per frame
- \( N \): number of contiguous carriers in a slot
- \( M \): number of OFDM symbols in a slot
- \( \alpha_{\text{slot}} \): mean value of the multipath fading coefficient
The Capacity function in this System

- $k$: user index, with $k = 1, \ldots, K$;
- $i$: slot index along frequency dimension, with $i = 0, \ldots, A - 1$;
- $j$: slot index along time dimension, with $j = 0, \ldots, B - 1$;
- $\bar{\alpha}_{SLOT_{i,j}}^k$: averaged multipath coefficient within the slots with indices $(i, j)$, for the $k$-th user.

- Capacity of SLOT$_{i,j}$ assigned to user $k$
  \[
  C_{SLOT_{i,j}}^k = N \cdot M \cdot B_p \cdot \frac{N_s}{N_s} \log_2 \left( 1 + \text{SNR}_{i,j}^k \right) \]
  for $k = 1, 2, \ldots, K$

- Maximum capacity each user
  \[
  C_{\text{max},k} = \sum_{i=0}^{A-1} \sum_{j=0}^{B-1} C_{SLOT_{i,j}}^k \quad \text{for } k = 1, 2, \ldots, K
  \]
Slot allocation matrix

- $X^k$
  - $x_{i,j}^k = \begin{cases} 
    1 & \text{SLOT}_{i,j} \text{ assigned to } k\text{-th user} \\
    0 & \text{SLOT}_{i,j} \text{ not assigned to } k\text{-th user}
  \end{cases}$

- Channel capacity assigned to user $k$
  
  $$C_k = \sum_{i=0}^{A-1} \sum_{j=0}^{B-1} x_{i,j}^k \cdot C_{\text{SLOT}_{i,j}}^k \text{ for } k = 1, 2, \ldots, K$$
OSDA (optimal slot dynamic allocation)

\[
\max_{\mathbf{x}} \sum_{k \in \Xi} \sum_{i=0}^{A-1} \sum_{j=0}^{B-1} x_{i,j}^k \cdot C_{\text{SLOT}_{i,j}}^k
\]

Subject to:

\[
\sum_{k \in \Xi} x_{i,j}^k = 1 \ \forall i, j
\]

\[
\sum_{i=0}^{A-1} \sum_{j=0}^{B-1} x_{i,j}^k \geq 1 \ \forall k \in \Xi
\]
Fair allocation

1) Initialization:
   a) \( R_k \leftarrow 0 \) for \( k = 1, \ldots, K \);
   b) \( S_k \leftarrow \emptyset \) for \( k = 1, \ldots, K \);
   c) \( S \leftarrow \{s(i, j) : i = 0, \ldots, A - 1, j = 0, \ldots, B - 1\} \);

2) for \( k = 1, \ldots, K \):
   a) find a slot \( s(i, j) \in S \) so that \( SNR_{i,j}^k \geq SNR_{n,m}^k \) for each slot index \((n, m)\) for which at least a free slot in \( S \) exists;
   b) \( S_k \leftarrow S_k \cup \{s(i, j)\} \);
   c) \( S \leftarrow S - \{s(i, j)\} \);
   d) \( R_k \leftarrow R_k + C_{\text{SLOT}^k_{i,j}} \);

3) while \( S \neq \emptyset \):
   a) find the user \( k \) so that \( R_k \leq R_u \) for each user \( u \);
   b) find the slot \( s(i, j) \in S \) so that \( SNR_{i,j}^k \geq SNR_{n,m}^k \) for each slot index \((n, m)\) for which at least a free slot in \( S \) exists;
   c) \( S_k \leftarrow S_k \cup \{s(i, j)\} \);
   d) \( S \leftarrow S - \{s(i, j)\} \);
   e) \( R_k \leftarrow R_k + C_{\text{SLOT}^k_{i,j}} \).
Proportional allocation

1) Initialization:
   a) compute $C_{\text{max},k}$ for $k = 1, \ldots, K$ accordingly to (6);
   b) $R_k \leftarrow 0$ for $k = 1, \ldots, K$;
   c) $S_k \leftarrow \emptyset$ for $k = 1, \ldots, K$;
   d) $S \leftarrow \{s(i, j) : i = 0, \ldots, A - 1, j = 0, \ldots, B - 1\}$;

2) for $k = 1, \ldots, K$:
   a) find a slot $s(i, j) \in S$ so that $SNR_{i,j}^k \geq SNR_{n,m}^k$ for each slot index $(n, m)$ for which at least a free slot in $S$ exists;
   b) $S_k \leftarrow S_k \cup \{s(i, j)\}$;
   c) $S \leftarrow S - \{s(i, j)\}$;
   d) $R_k \leftarrow R_k + C_{\text{SLOT},i,k}$;

3) while $S \neq \emptyset$:
   a) find the user $k$ so that $\frac{R_k}{C_{\text{max},k}} \leq \frac{R_u}{C_{\text{max},u}}$ for each user $u$;
   b) find a slot $s(i, j) \in S$ so that $SNR_{i,j}^k \geq SNR_{n,m}^k$ for each slot index $(n, m)$ for which at least a free slot in $S$ exists;
   c) $S_k \leftarrow S_k \cup \{s(i, j)\}$;
   d) $S \leftarrow S - \{s(i, j)\}$;
   e) $R_k \leftarrow R_k + C_{\text{SLOT},i,j}$.

- $s(i, j)$: the slot of frequency index $i$ and time index $j$;
- $S$: the set of free slots;
- $S_k$: the set of slots assigned to the $k$-th user;
- $R_k$: the capacity assigned to the $k$-th user.
Equal capacity increment allocation

- Consider an TDMA system
  \[ C'_k = \frac{1}{K} C_{\text{max},k} = \frac{1}{K} \sum_{i=0}^{A-1} \sum_{j=0}^{B-1} C_{\text{SLOT}_{i,j}} \]

- Capacity increment for user k
  \[ G_k = R_k - C'_k \]
Equal capacity Increment allocation

- \( s(i, j) \): the slot of frequency index \( i \) and time index \( j \);
- \( S \): the set of free slots;
- \( S_k \): the set of slots assigned to the \( k \)-th user;
- \( R_k \): the capacity assigned to the \( k \)-th user.

1) **Initialization:**
   
   a) compute \( C'_k \) for \( k = 1, \ldots, K \) accordingly to (22);
   
   b) \( R_k \leftarrow 0 \) for \( k = 1, \ldots, K \);
   
   c) \( G_k \leftarrow -C'_k \) for \( k = 1, \ldots, K \);
   
   d) \( S_k \leftarrow \emptyset \) for \( k = 1, \ldots, K \);
   
   e) \( S \leftarrow \{ s(i, j) : i = 0, \ldots, A - 1, \\
   \quad j = 0, \ldots, B - 1 \} \);

2) **while** \( S \neq \emptyset \):
   
   a) find the user \( k \) so that \( G_k \leq G_u \) for each user \( u \);
   
   b) find a slot \( s(i, j) \in S \) so that \( SNR^k_{i,j} \geq SNR^k_{n,m} \) for each slot index \( (n, m) \) for which at least a free slot in \( S \) exists;
   
   c) \( S_k \leftarrow S_k \cup \{ s(i, j) \} \);
   
   d) \( S \leftarrow S - \{ s(i, j) \} \);
   
   e) \( R_k \leftarrow R_k + C_{\text{SLOT}^k_{i,j}} \);
   
   f) \( G_k \leftarrow R_k - C'_k \) for \( k = 0, \ldots, K - 1 \).
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System Bit Error Rate comparisons for different slot allocation strategies (pathloss effects have been neglected)
System throughput comparisons for different slot allocation strategies (pathloss effects have been neglected)
User throughput comparisons for different slot allocation strategies and pathloss channel case
User Bit Error Rate comparisons for different slot allocation strategies, and pathloss channel case
User throughput comparisons for different slot allocation strategies with 64-QAM modulation, and pathloss channel case
User Bit Error Rate comparisons for different slot allocation strategies with 64-QAM modulation, and pathloss channel case
User throughput comparisons for different slot allocation strategies, for the case of pathloss channel, and users close to the BS
User throughput comparisons for different slot allocation strategies, for the case of pathloss channel, and users far from the BS.
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Conclusion

• Consider a flexible OFDMA wireless system
• Propose two algorithm based on estimation of the channel capacity
  ▫ Proportional allocation
  ▫ Equal capacity increment allocation
• Achieve a better trade-off between fairness and bandwidth efficiency with respect to fair allocation
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Introduction and motivation

- A scenario (802.16j transparent mode) for the bandwidth arbitration among MSs and RSs and is caused from
  - There is no RS cover the MS
  - $\text{RS}_{\text{SNR}} < \text{MS}_{\text{SNR}}$

Therefore, it is a challenge issue that how to decide the subframe size between access zone or realy zone in DL or UL
Related Works

  ▫ this paper focuses on the diversity of users in the 802.16e OFDMA system

• Eugene Visotsky et. al., “On the Uplink Capacity of an 802.16j System,” 2008 WCNC.
  ▫ Consider the $\gamma$(use time domain) to divide the access zone and relay zone, but the paper doesn’t consider the diversity for different users
System model and assuming

- IEEE 802.16j OFDMA system
- Decode-and-forward
- Because the relay station does not have the buffer to queue the packets, it has to be transmitted directly to be BS
- Keep the transmissions constant
- Only a MS1 and a RS (include a MS2) in our system
- The basic unit of bandwidth allocation is depend on slots (assemble by subcarrier and OFDM symbol)
System model and assuming

- IEEE 802.16j OFDMA system
- Decode-and-forward
- Because the relay station don’t have the buffer to queue the packets, the packets have to be transmitted to BS in a frame
- Keep the transmit power in all stations constant
- Only a MS1 and a RS (include a MS2) in our system
- The basic unit of bandwidth allocation is depend on slots (assemble by subcarrier and OFDM symbol)
Heuristic Approach to Diversity Bandwidth Allocation in the 802.16j OFDMA System

- We employ a “zone line” to divide the frame size between access zone and relay zone
  - We select the location of zone line based on users’ capacity
- Allocate the slots of access zone to MS1 and MS2 based on the utility of MS1 and MS2
  - If BS allocates x slots to MS2, the function RS(x) is calculated for MS2 in the relay zone
    - RS access zone allocates slots from right to left.
- If relay zone have free slots, we shift the “zone line” to the right to compute new allocation results until all slots in the frame are empty

Note that the “zone line” is virtual line concept and it may not be a straight line
Consider multiuser diversity in 802.16j

- We employ a “zone line” to divide the frame size between access zone
How to select slot

- SNR
- Keep the block for each user
- Guarantee user transmission rate
- Fairness
Thank you^___^