Adaptive IEEE 802.11 MAC Protocol for high efficiency MC-CDMA WLANs

15. FFV Workshop
Dr.-Ing. Georgios Orfanos
Overview

• MC-CDMA
• C-DCF Main protocol
• C-DCF OFDM/MC-CDMA capacity comparison
• Smart Backoff
• Frequency adaptation
• Crosslayer optimisation
• Multihop extension
• Centralized mode
• Conclusions
MC-CDMA (I)

- Combination of SS and OFDM
- Frequency spreading
- Frequency diversity
- IFFT / FFT realization of multicarrier modulation
- Simultaneous transmissions in the same frequency, through division of the spectrum in parallel channels => codechannels

- Major advantages for MAC protocol design:
  - Effective protocol overhead reduction
  - Contention reduction
  - Multichannel structure: higher complexity, more degrees of freedom for optimization

G.Orfanos, 15. FFV Workshop, 21.11.2008
MC-CDMA (II)

Link Level Performance of MC-CDMA

• PHY modes from IEEE 802.11a/e
• Convolutional encoder $K=7$
• Packet length: 1514 Bytes
• $a_{CP} = 80\%$

G.Orfanos, 15. FFV Workshop, 21.11.2008
C-DCF Main protocol

- CSMA / CA with 4 parallel codechannels
  - multichannel system
- Selection of codechannel
  - random
  - first transfer on cch1
- Data transfer: DCF
- NAV per codechannel
  - each station monitors optionally one or all codechannels
- Power control over RTS / CTS
  - for all data frames
C-DCF
OFDM/MC-CDMA capacity comparison

• 1024 Bytes MAC SDUs

![Bar chart comparing OFDM and MC-CDMA spectral efficiency](chart.png)

G.Orfanos, 15. FFV Workshop, 21.11.2008
C-DCF

OFDM/MC-CDMA capacity comparison
WigWam AP3 high speed PHY-layer parameters

- $F = 5.25$ GHz
- $\text{BW} = 100\text{MHz}$
- $N_{\text{subcarriers}} = 596$
- $\Delta f = 0.15625$ MHz
- $T_{\text{symbol}} = 6.8\mu\text{sec}$
- $a_{\text{SlotTime, SIFS, Preamble}} = 4\mu\text{sec}$
- $\text{DIFS} = 8\mu\text{sec}$
- PHY-rate Data packets: 64QAM3/4

- PHY-layer capacity: 330Mbit/sec

G.Orfanos, 15. FFV Workshop, 21.11.2008
Smart Backoff (I)

- Backoff procedure spanning over many cchs
- Backoff Time = $\text{Random} \cdot a\text{SlotTime}$
  - Another cch seems idle
  - Another cch is determined idle
  - No cch is idle

G.Orfanos, 15. FFV Workshop, 21.11.2008
Smart Backoff (II)

Smart Backoff discussion

+ Load balance among cchs
  smoothing interference
  Fair resource utilization
  same competition in each cch
  Easy to implement with CDMA
  Priorization for MSs
  Enable parallel transmission

- Static codechannel allocation:
  better optimization
Frequency adaptation

- Based on MUD and PC
- Solution for Near-Far Effects with higher PHY-modes
- Calculate link balance as in PC
- Change frequency band if needed Tx-Power exceeds threshold
- Alternatively change set of subcarriers
Crosslayer optimization (I)

- Operation on MUD high efficiency area
- Reduction of relative delay among concurrent transmissions
- Synchronization on multicarrier symbol level
  - Adaptation of all timing parameters to multiples of a multicarrier symbol duration
- Isochronous operation due to:
  - Imperfect clocks at stations
  - Propagation delay of decentralized system

G.Orfanos, 15. FFV Workshop, 21.11.2008
Crosslayer optimization (II)

- 2 available frequency channels
- Synchronization accuracy: 10% multicarrier symbol duration
- Superiority of crosslayer adaptation towards other methods

G. Orfanos, 15. FFV Workshop, 21.11.2008
Multihop extension (I)

Multihop guard interval, extended NAV

- Multihop guard interval to prioritize forwarder
  - Duration of one complete transmission window
- Smart Backoff at forwarders for bottleneck avoidance
  - Combined with parallel transmission
- Extended NAV
  - Duration, cch, MSs

G. Orfanos, 15. FFV Workshop, 21.11.2008
Multihop extension (II)

Typical scenario and comparative simulation results
Centralized mode (I)

- Support for Aps and high throughput /low delay applications
- Optimum CP/CFP separation in time and code domain reduces initialization delay avoids strict timing arrangements between MSs operation in two modes.
Centralized mode (II) performance

<table>
<thead>
<tr>
<th>Superframe length</th>
<th>C-DCF Max. theoretical throughput on 4 cchs</th>
<th>IEEE 802.11e</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 msec</td>
<td>40.96 Mbit/sec</td>
<td>25.39 Mbit/sec</td>
</tr>
<tr>
<td>40 msec</td>
<td>40.96 Mbit/sec</td>
<td>25.80 Mbit/sec</td>
</tr>
<tr>
<td>100 msec</td>
<td>41.61 Mbit/sec</td>
<td>26.05 Mbit/sec</td>
</tr>
</tbody>
</table>

1KByte
100% CFP

CDF of queueing delay per MS with 2.8 Mbit/sec/MS Poisson distributed offered load. Mixed operation.
P(delay<11.5msec)=90%
Delay_max=18msec (prio 1)
=25msec (prio 2)

G.Orfanos, 15. FFV Workshop, 21.11.2008
Conclusions

• MC-CDMA reduces overhead, leading to high capacity
• Smart Backoff for prioritization and load balance
• Adaptation function to exploit high capacity and avoid near-far-effects
• Cross layer optimization boosts performance and improves fairness
• Multichannel structure allowing good separation of users (codechannels)
  – Essential since one user seldom demands whole Gbit capacity

• Reservation of cch for QoS guaranty when higher SF is applied
Thank you for your attention!

Dr.-Ing. Georgios Orfanos
gorfanos@epo.org