Incorporating Dynamic OFDMA in IEEE 802.11

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Acknowledgements

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Motivation

- OFDM-bases physical layers are commonly used for high-speed wireless networks

- Currently used schemes
  - transmit packets sequentially using all OFDM sub-carriers
  - employ the same modulation/coding on all sub-carriers

- Dynamic OFDM schemes are known to outperform these traditional schemes as they
  - choose a modulation/coding scheme individually per sub-carrier (according to the current sub-carrier channel gain)
  - may transmit packets in parallel to several STAs in the downlink using FDM by assigning sub-carrier sub-sets per STA

- This presentation shows the potential of Dynamic OFDM to enhance upcoming 802.11 systems.
“Classical OFDM”

- All sub-carriers assigned to one STA
- Same modulation/coding scheme applied to all sub-carriers
P2P-Mode: Dynamic Single-User OFDM

- All sub-carriers assigned to one STA
- Modulation/coding per sub-carrier differs according to current channel gain
- Benefit from lower error probability

P2P-DynOFDM: React to frequency variations by specific modulation/power setting per subcarrier
P2MP-Mode: Dynamic Multi-User OFDM

- Subsets of sub-carriers are assigned to different STAs
- Modulation/coding per sub-carrier according to current channel gain for the specific STA
- Additionally: benefit from multi-user diversity

P2MP-Mode: Enable simultaneous data transmission to different stations via (channel dependent) OFDMA → Exploit multi-user diversity
Required overhead to use Dynamic OFDM

- In order to choose an (optimal) modulation/coding per sub-carrier, we need to:
  - estimate the channel gain per sub-carrier for each transmission
  - signal the used modulation/coding per sub-carrier from the transmitter to the receiver.

- Additionally, for the multi-user case (parallel transmission of packets), we have to:
  - signal the assignment of sub-carrier sets from the transmitter to the receiver.

- Performance evaluation depends on the technical realization of channel acquisition and signaling.

- The following results include all the required overhead if Dynamic OFDM were to be included in 802.11-2007 assuring downward compatibility with legacy devices.
Incorporation of Dynamic OFDM in 802.11

- **Dynamic Single-User OFDM [1,4-6]**
  - different modulation per sub-carrier according to sub-carrier channel gain

- **Dynamic Multi-User OFDM [2]**
  - additionally exploit multi-user diversity

→ Protocol overhead to include Dynamic OFDM considered in performance evaluation
Performance Evaluation

Comparison state-of-the art IEEE 802.11n with Dynamic OFDM Enhancements:

- Channel Model / Simulation Details

- Results: Exploiting the degrees of freedom
  - Baseline experiments
  - Reduce MAC overhead ↔ enable frame aggregation
  - Exploit Multi User Diversity ↔ enable P2MP mode
  - Add spatial layers
802.11n & Channel Model

- Simulations for 11n considering
  - A-MPDUs Frame Aggregation [10]
  - 2x2x20 MHz Spatial Multiplexing [10]
  - Channel Model E (Large Office) [8,9]

- Sub-Carrier Specific Attenuation
  - MatLab used to generate impulse response of channel for each transmission [8,11]
  - Impulse response used to calculate channel matrix $H$
    --> sub-carrier specific attenuation

- Results of reference simulations verified against results of IEEE 802.11n WG (c.f. 11-07/2860)
Simulation Details

- Large PDUs (1536 Byte, RTS/CTS enabled for 11n) & small ones (200 Byte, RTS/CTS disabled for 11n)

- Saturation mode (always “enough” packets in queue)

- P2P scenario: one transmitter, one receiver, no further stations, one-way traffic only

- P2MP scenario: one transmitter, several (4) receivers, no further stations, one-way traffic only, all receivers at same distance to transmitter

- Performance metric: MAC Goodput [bit/s]
Results I – Baseline

- 1 spatial stream, no frame aggr., P2P scenario

Small PDUs (200 Byte)  Large PDUs (1536 Byte)

DynOFDM can dramatically improve system performance for low SNRs (300%) for small packets. It constantly outperforms 11n for large packets.
Results II – Reduction of MAC Overhead

- 1 SS, frame aggr. activated, P2P scenario

Small PDUs (200 Byte) – FA with 4 PDUs

Large PDUs (1536 Byte) – FA with 2 PDUs

By leveraging the protocol overhead (for both, 11n and DynOFDM), DynOFDM always outperforms 802.11n
Results III – Adding Multi-user Diversity

- 1 SS, frame aggr. activated, P2MP (4 STA) scenario
- Equal PDU number aggregated into one channel access

Small PDUs (200 Byte) – FA with 16 PDUs for 11n, FA with 4 PDUs for 11DYN

Large PDUs (1536 Byte) – FA with 8 PDUs for 11n, FA with 2 PDUs for 11DYN

Overhead due to post-backoff leverages protocol overhead for 11n and DynOFDM. Aggregated throughput increased by approx. 50%
Results IV – Adding Spatial Layers

- 2 SS, frame aggr. active, P2MP scenario (4 STA)

Small PDUs (200 Byte) – FA with 16 PDUs for 11n, FA with 2 PDUs for 11DYN

Large PDUs (1536 Byte) – FA with 8 PDUs for 11n, FA with 2 PDUs for 11DYN

DynOFDM outperforms IEEE 802.11n except for small packets transmitted for high SNRs: 4 terminals are not enough to fully exploit the diversity for more SSs
Summary

- It is possible to incorporate Dynamic OFDM in IEEE 802.11 upholding backward compatibility with legacy devices (even down to 1st generation WLANs).

- Dynamic OFDM can easily outperform the upcoming IEEE 802.11n system for large packet sizes and in most cases also for very small packets considering all the required protocol overhead.

- Both, exploiting the frequency diversity per sub-carrier as well as the multi-user diversity is one main focus of future WLAN system (IEEE 802.11 TGac). The presented ideas and results are actively fed into this task group.
References

[1] 11-07/0720r2 -- Dynamic Point-to-Point OFDM Adaptation for IEEE 802.11a/g Systems
[2] 11-07/2062r1 -- Dynamic Multi-user OFDM for 802.11 systems
[3] 11-07/2187r1 -- Another resource to exploit: multi-user diversity
[7] 11-06/0067r3 -- TGn Joint Proposal Phy Results
[8] 11-03/940r4 -- TGn Channel Models
[9] 11-03/802r23 -- Usage Models
[10] TGn Draft most rece3int verstion
Thank you for your attention
Backup Slides
P2MP OFDM for 802.11: Modified PLCP Header

- 1st 24 bits of PLCP header in compliance with legacy 802.11
  --> everybody may decode the header and discard it if

- the RATE field indicates Dynamic OFDM to be used in the payload

- Additional signaling indicates used mode per sub-carrier and terminal