Dynamic Multi-user OFDM for 802.11 systems

Date: 2007-07-15

Authors:

Name	Company	Address	Phone	email
James Gross	Technical University Berlin	Einsteinufer 25 10587 Berlin, Germany	+49-30-314-23830	gross@tkn.tu-berlin.de
Marc Emmelmann			+49-30-314-24580	emmelmann@ieee.org
Oscar Puñal				
Adam Wolisz				awo@ieee.org

Abstract

Dynamic OFDM schemes employ a per sub-carrier modulation/coding assignment considering the different channel gains per sub-carrier. It is well known that this scheme dramatically decreases the bit- and packet error rate of OFDM systems. Hence, it can increase the performance of WLANs. In addition, further performance gain can be achieved by employing multi-user diversity.

This talk presents a performance evaluation of single- and multi-user dynamic OFDM considering all the required overhead in terms of signaling and channel gain estimation.

Results show that Dynamic OFDM achieves a tremendous performance gain as compared to "classical" OFDM and should hence be considered for upcoming WLAN systems.

It is recommended that IEEE VHT SG should include the "consideration of dynamic OFDM schemes" in the PAR/5C.

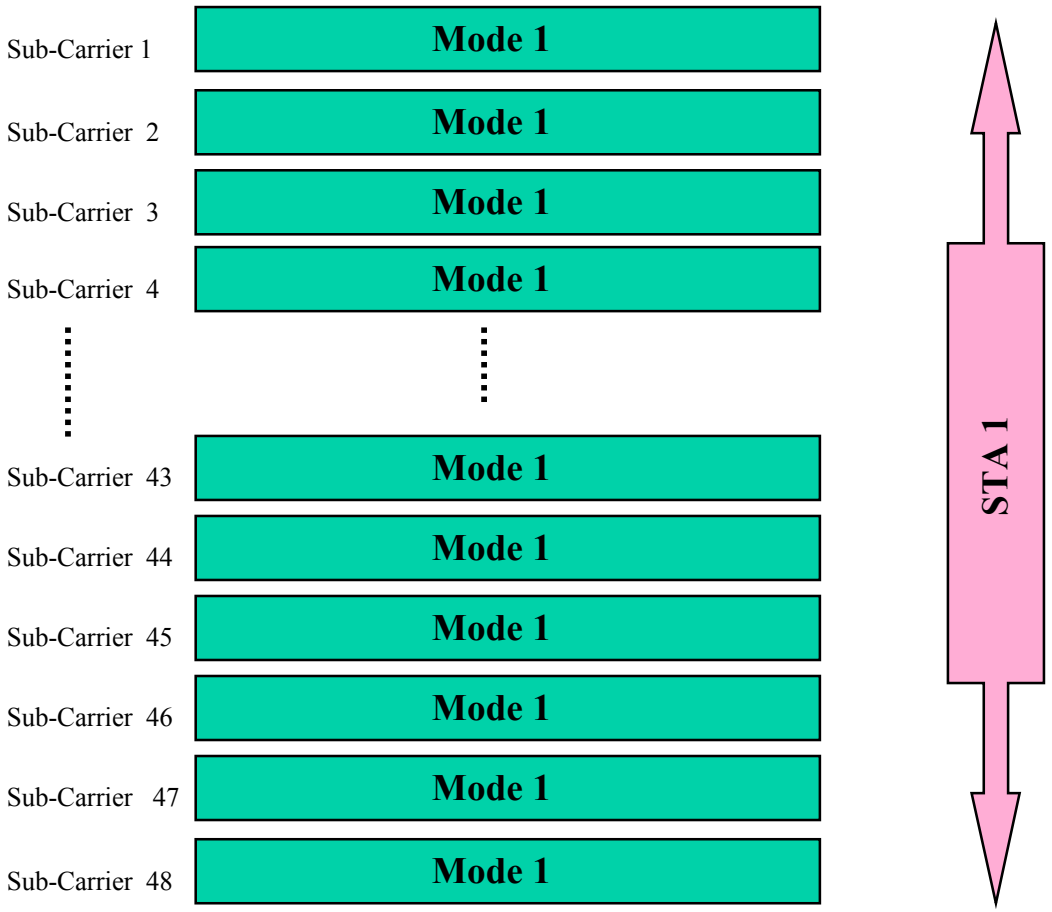
Motivation

- **OFDM-based 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.**

Outline

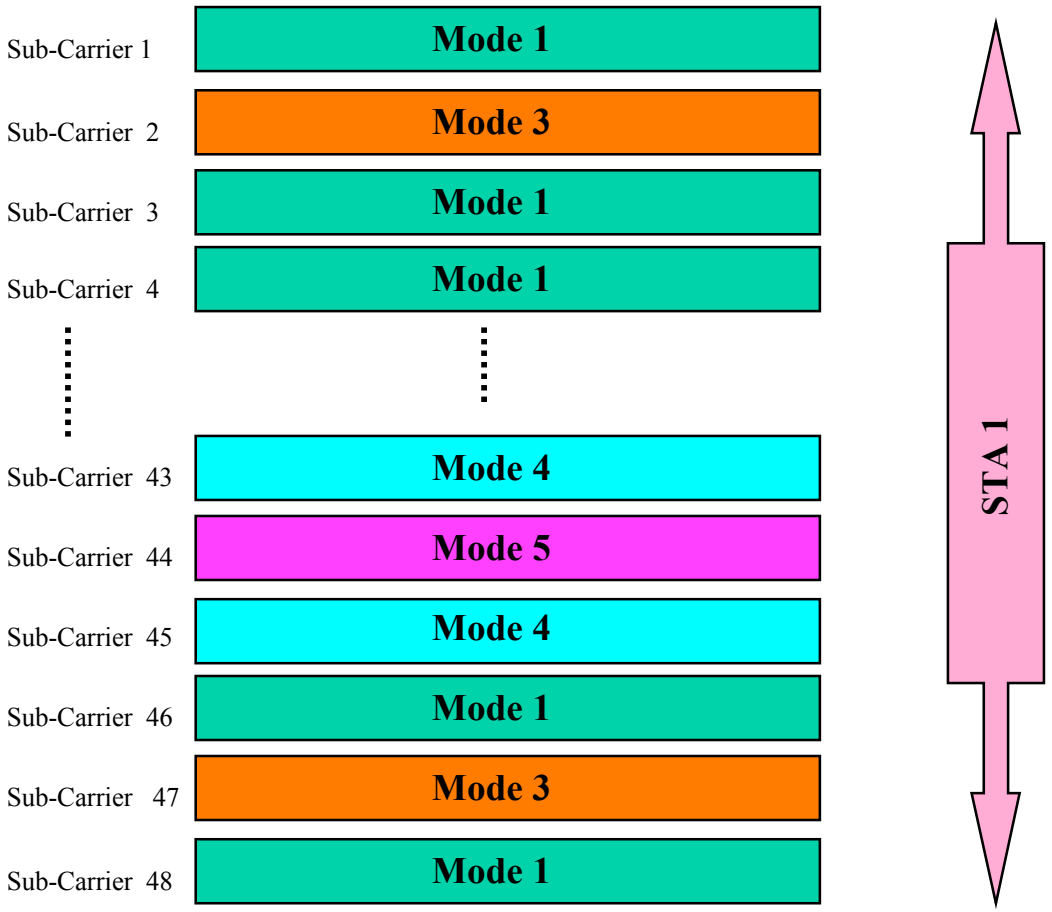
- **Overview (Dynamic) OFDM**
  - "Classical" OFDM / State-of-the Art
  - Single-User OFDM
  - Multi-User OFDM
- **How to include Dynamic OFDM in (existing) WLANs**
  - Required overhead
  - One possible technical realization (downward compatible to 802.11-2007)
- **Performance evaluation**
  - Saturation mode goodput (downlink)
  - End-to-end delay of (bi-directional) G.711 traffic
- **Summary & Conclusion**

"Classical OFDM"



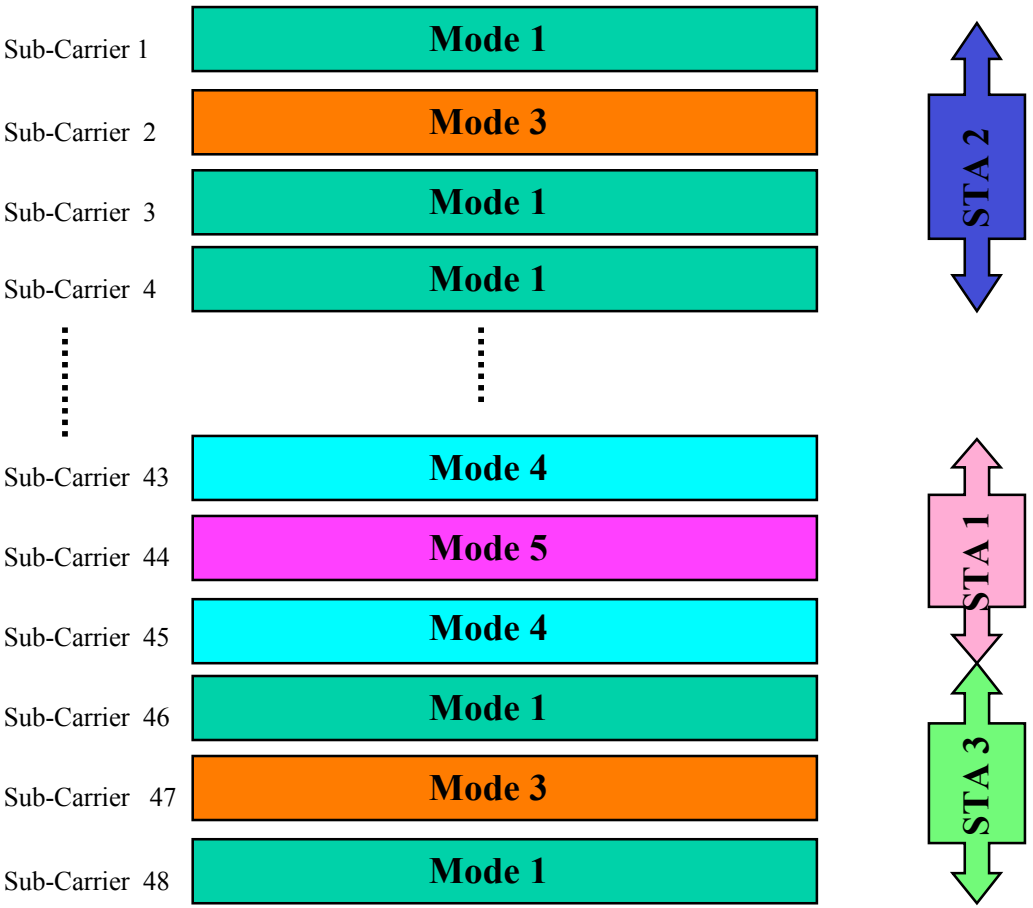
- All sub-carriers assigned to one STA
- Same modulation/coding scheme applied to all sub-carriers

"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

"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

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

  and

  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.

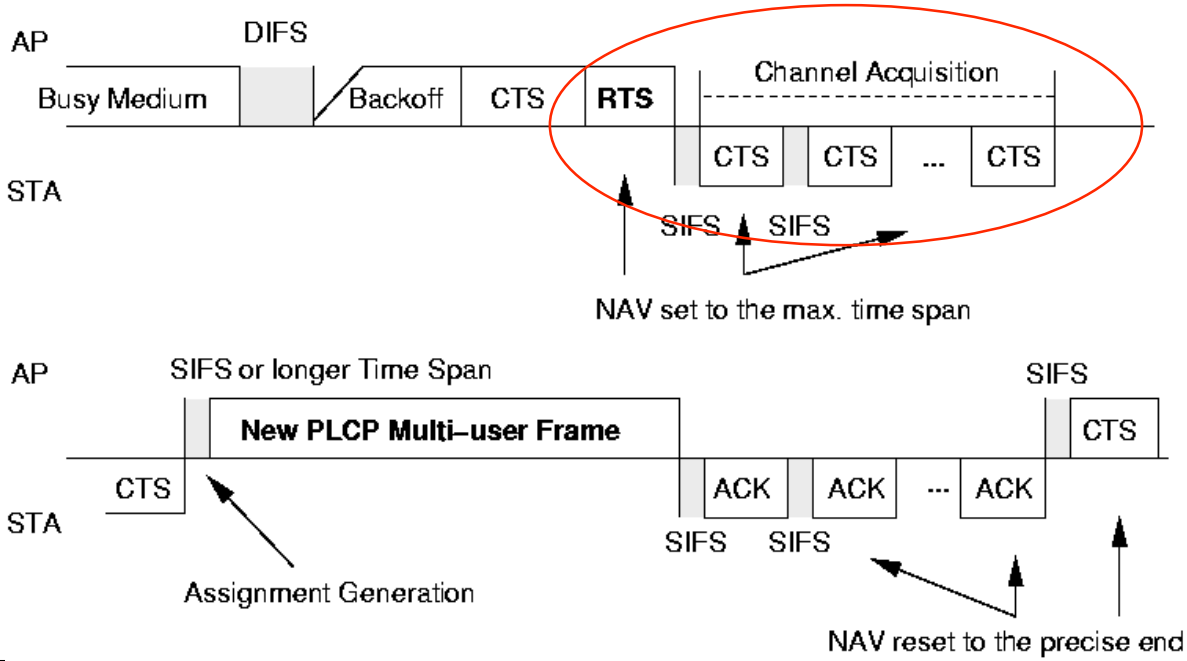
- **Modifications to some stages of the transmitter / receiver chain**

Dynamic Multi-User OFDM for 802.11:

- **Performance evaluation depends on the technical realization of channel acquisition and signaling.**
- **Thus, the following slides present *one possible* approach to include dynamic multi-user OFDM in 802.11 assuring downward compatibility.**
- **The proposed protocol extensions are only presented to evaluate the performance gain achievable with dynamic OFDM and are explicitly not proposed as a preferred method enhancing 802.11.**
- **Please note: Details for Single-User OFDM are given in 11-07/720r2.**

Dynamic Multi-User OFDM for 802.11: Channel acquisition

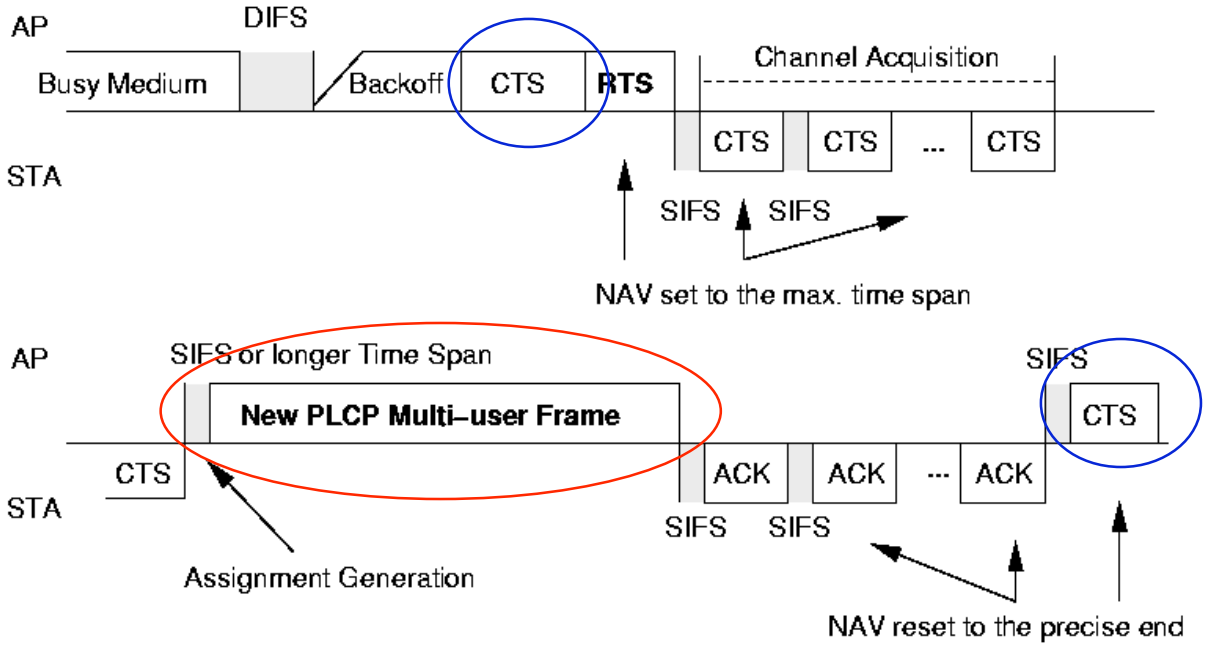
- **Mandatory RTS-CTS**
  - Extension of the Single-User OFDM case as presented in 11-07/xxxx
  - New for multi-user OFDM: new RTS contains "polling" list, all stations to be address in the multi-user transmission respond with a CTS



Dynamic Multi-User OFDM for 802.11: sub-carrier assignments & NAV setting

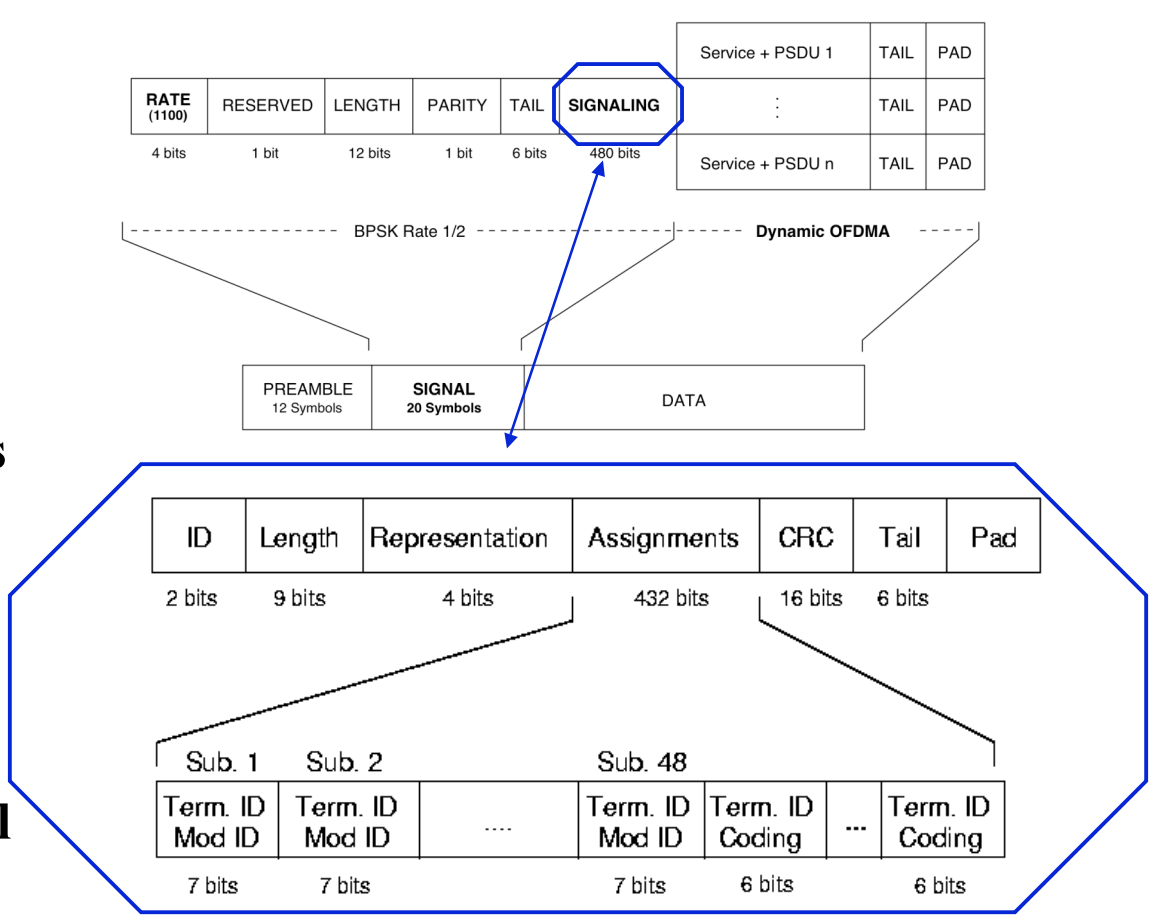
- **Signaling of sub-carrier assignments: Included in a modified header of a PLCP Frame (next slide)**

- **As legacy STAs cannot decode the new PLCP payload and the modified RTS (multi-user case only), the transmission is guarded with a CTS-to-self**



Dynamic Multi-User 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**

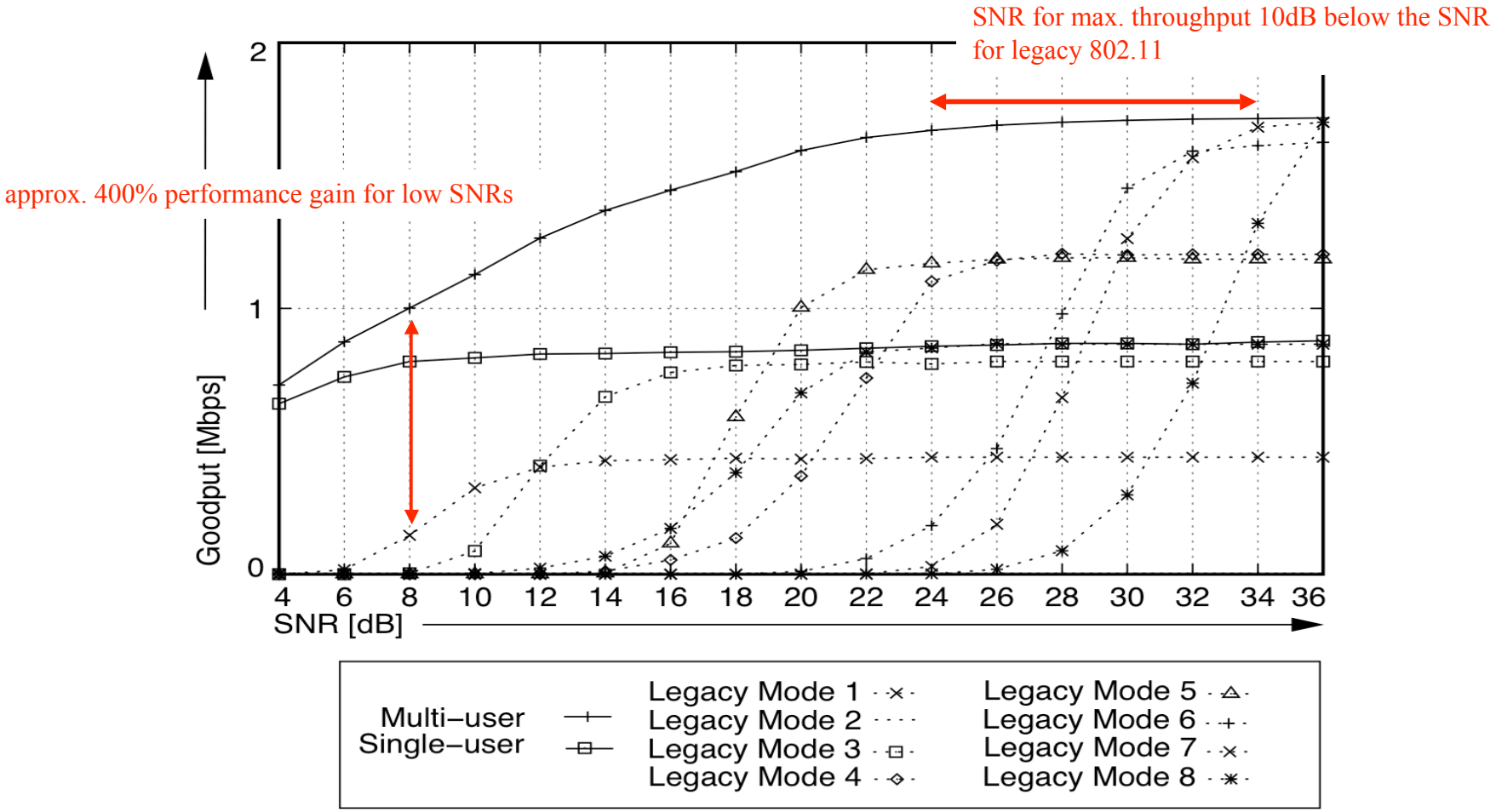


Performance Evaluation

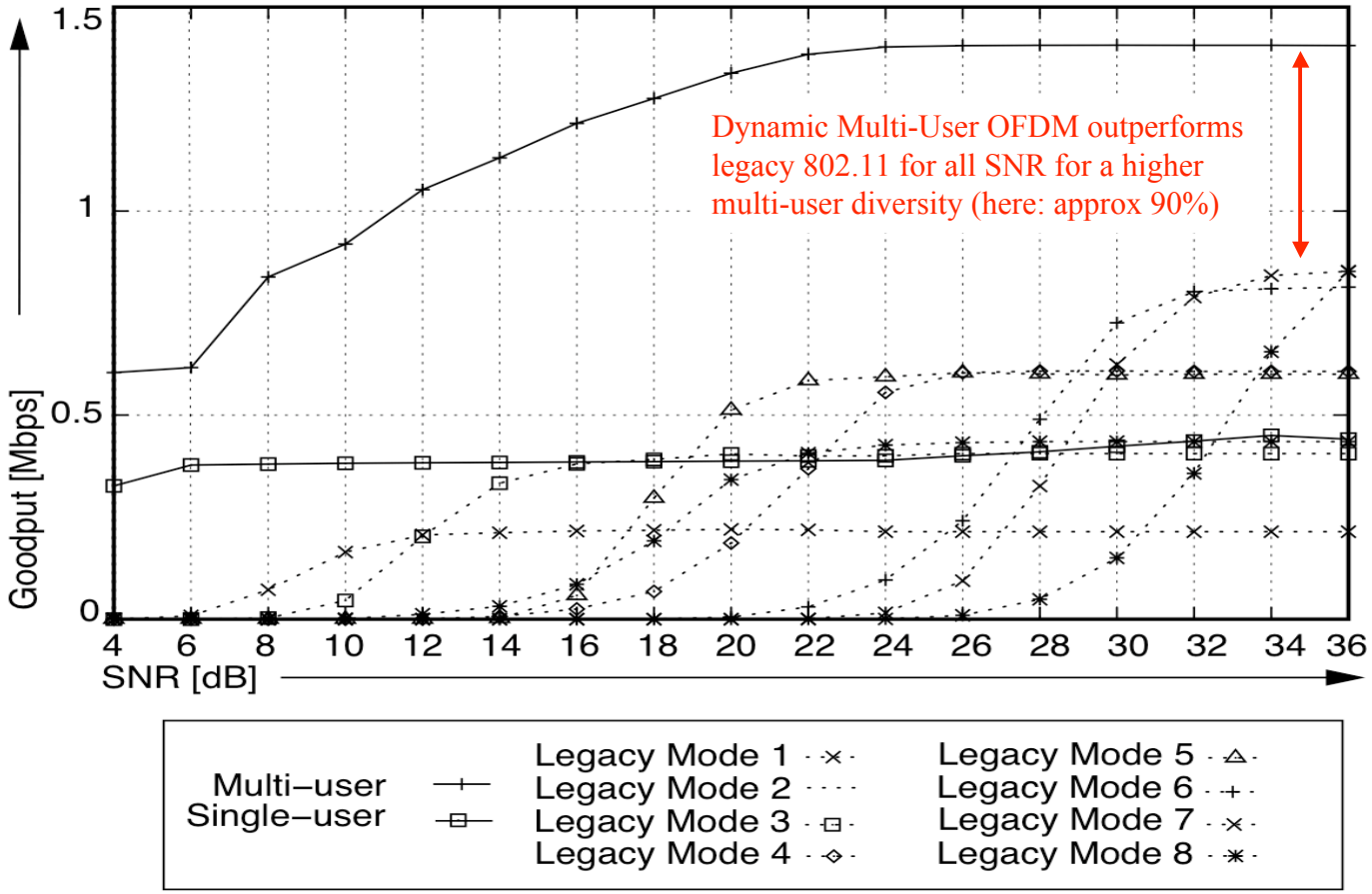
- **Two Metrics: Goodput and End-2-End Delay**

- **Scenario for Goodput Metric:**
  - Saturation mode goodput, uni-directional downlink transmission
  - Two packet sizes: 228 byte and 1536 byte
  - Comparing Dynamic OFDM (Single- and Multi-User Mode) with
    - legacy 802.11a without RTS/CTS
    - legacy 802.11a using RTS/CTS
- **Scenario for End-2-End Delay (including queuing times):**
  - Bidirectional G.711-compliant traffic
  - Multi-User Dynamic OFDM in the Downlink,
    Single-User Dynamic OFDM in the Uplink
  - Comparison with legacy 802.11a without RTS/CTS

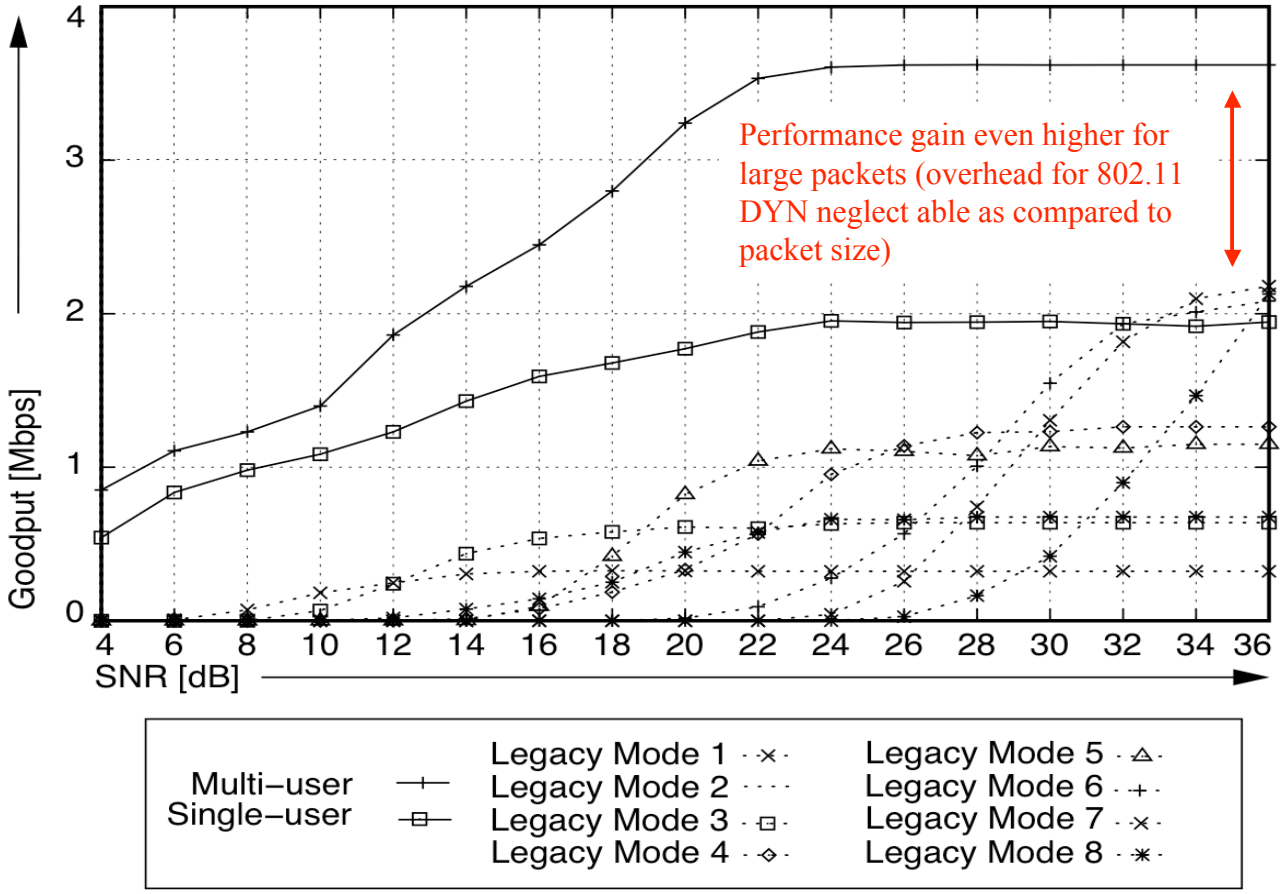
Saturation mode goodput results of 802.11 DYN (single-user and multi-user mode) and all legacy IEEE 802.11a modes without RTS/CTS for various different SNR levels for a packet size of 228 Byte. J=4 stations are present in the cell



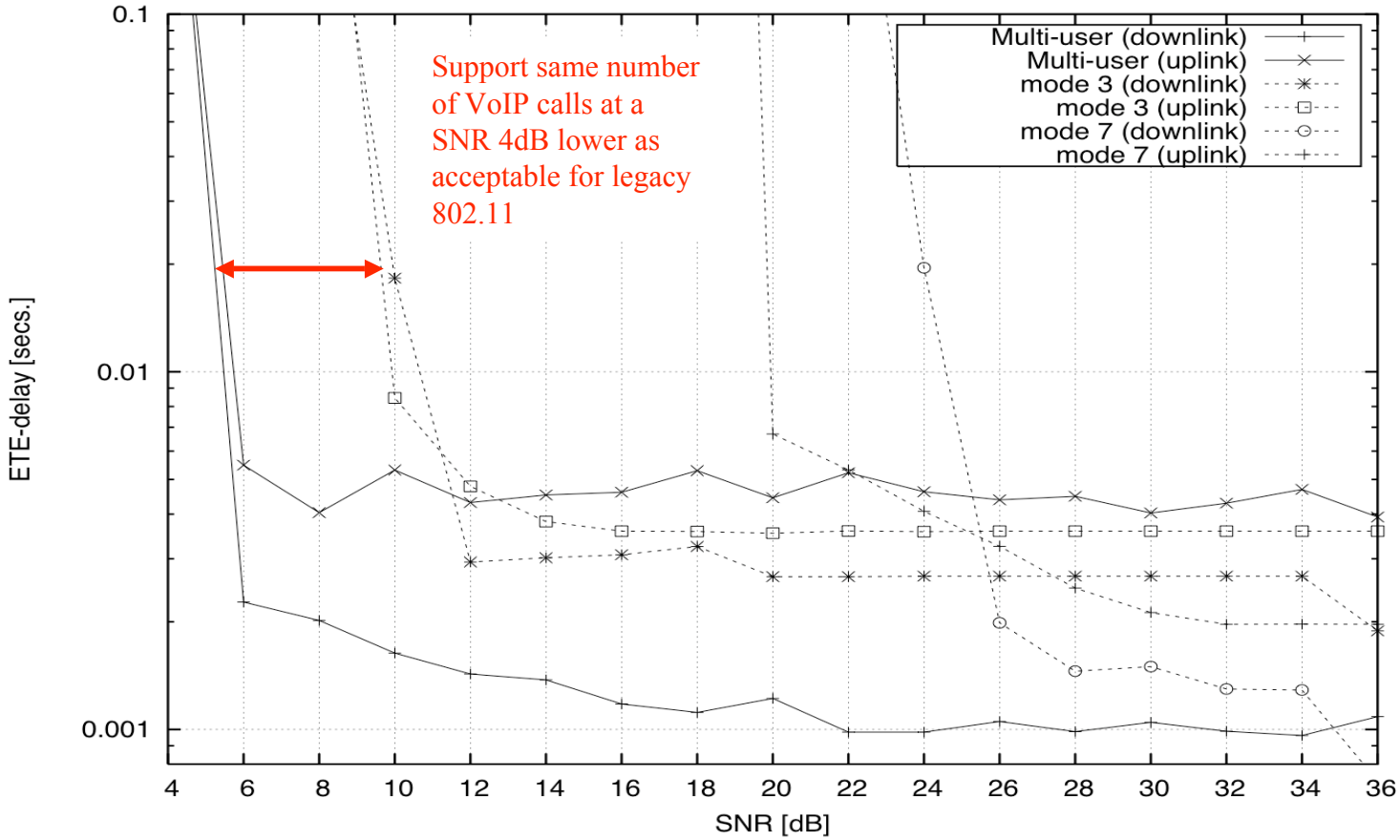
Saturation mode goodput results of 802.11 DYN (single-user and multi-user mode) and all legacy IEEE 802.11a modes without RTS/CTS for various different SNR levels for a packet size of 228 Byte. J=8 stations are present in the cell



Saturation mode goodput results of 802.11 DYN (single-user and multi-user mode) and all legacy IEEE 802.11a modes with RTS/CTS frame exchange for various different SNR levels for a packet size of 1536 Byte. J=8 stations are present in the cell



Average delay over SNR for 802.11 DYN Multi-user and legacy IEEE 802.11a without RTS/CTS frame exchange for the G.711 VoIP traffic scenario with 64 kbps net rate per flow. J=15 stations are present in the cell



Summary & Conclusion

- **Dynamic OFDM improves the performance of WLAN systems even considering the cost of the additional signaling overhead**

- **Still lots of work to do, e.g.**
  - Comparison with 802.11n
  - Further evaluations, e.g.: supportable number of VoIP calls per cell at given SNR
  - other ....

- **Nevertheless, preliminary results show that:**

IEEE VHT SG should include the
"*Consideration of Dynamic OFDM*"
in the PAR/5C.

References

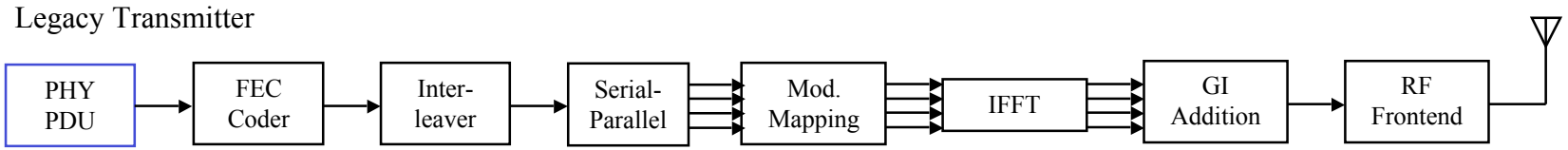
- J. Gross, M. Emmelmann, O. Puñal, and A. Wolisz, ”Dynamic Point-to-Point OFDM Adaptation for IEEE 802.11 Systems,” accepted for publication at IEEE/ACM International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM), October 2007.

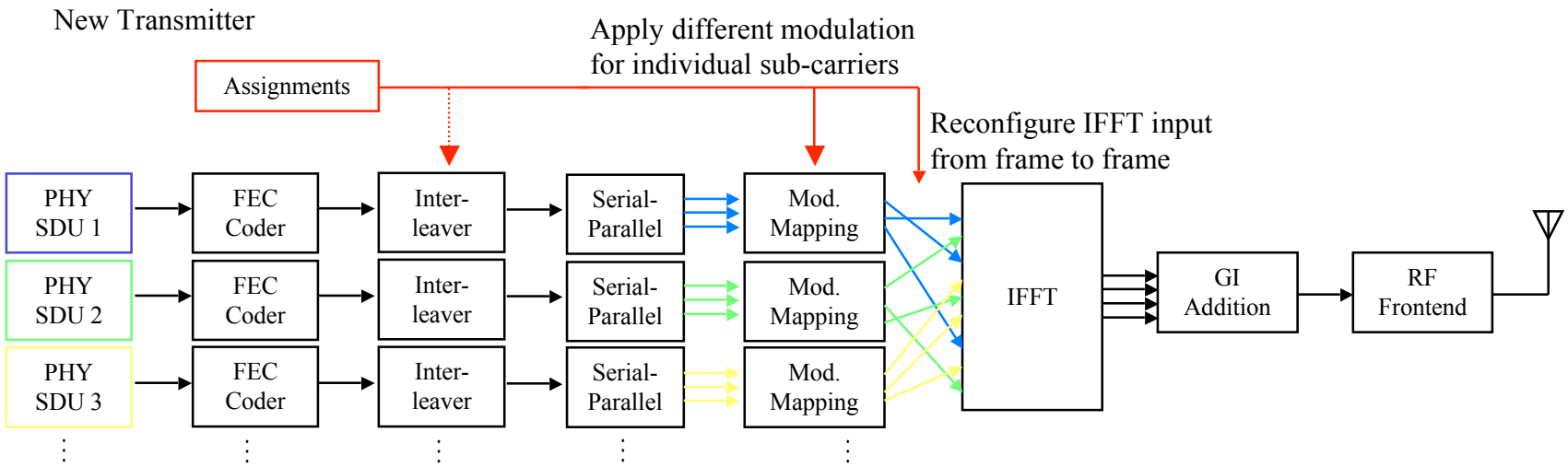
- J. Gross, M. Emmelmann, O. Puñal, and A. Wolisz: 802.11 DYN: Protocol Extension for the Application of Dynamic OFDM(A) Schemes in 802.11a/g Systems, Technical Report TKN-07-002, Telecommunication Networks Group, Technische Universitaet Berlin, May 2007. Available at www.tkn.tu-berlin.de

- J. Gross, M. Emmelmann, O. Puñal, and A. Wolisz: Dynamic Point-to-Point OFDMA Adaptation for IEEE 802.11a/g Systems, doc. 11-07/720, IEEE 802.11 WNG SC Wireless Next Generation Standing Committee, Montreal, Canada, May 14 -- 18 2007.

Appendix

Hardware Modifications I

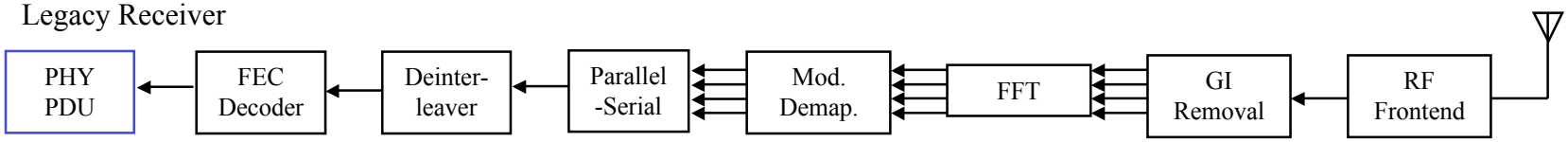




FEC Coder, Interleaver, S/P, Mod. Mapping: Could be realized by a single unit each, which processes the different SDUs corresponding to control information at a higher speed

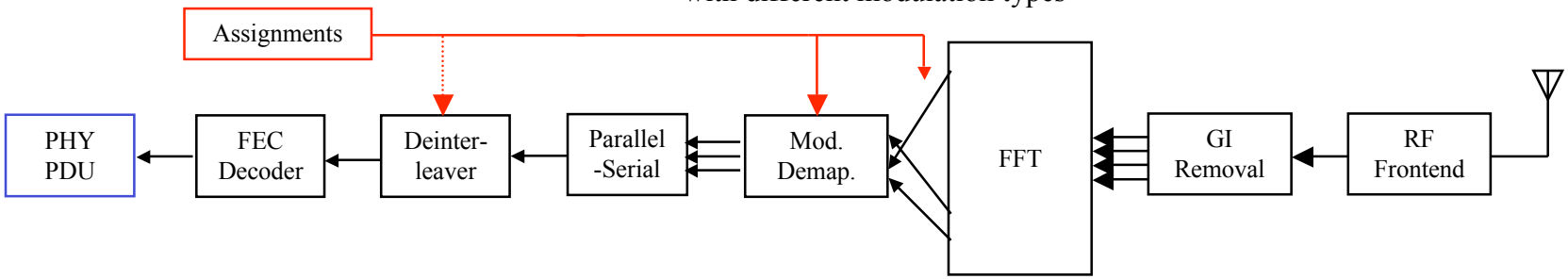
Hardware Modifications II

Legacy Receiver



New Receiver

Select FFT output per frame – demodulate individual sub-carriers with different modulation types



Downward compatible approach to extend 802.11 with Dynamic OFDM

- **Main protocol extensions:**
  - Estimation of sub-carrier gain:
    - Mandatory RTS/CTS a prior each transmission
    - Compliant to legacy 802.11-2007 for Single-User OFDM
    - Modified for Multi-User OFDM
  - Signaling of sub-carrier assignments:
    - Extension of PLCP Header contains information on the used modulation/coding for each sub-carrier
    - Extension additionally includes assignment of sub-carrier sets to STAs for Multi-user OFDM
  - Additional CTS-2-Self sets the NAV for legacy STAs as they cannot decode the MPDU transmitted with dynamic OFDM (hence: cannot read duration field)
- **Details for Single-User OFDM are given in 11-07/xxx,**
- **Multi-User OFDM transmission sequence is discussed in the Appendix**