

Dynamic Point-to-Point OFDM Adaptation for IEEE 802.11a/g Systems

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Abstract

This presentation evaluates a possible extension of 802.11a/g with dynamic OFDM.

In particular, a possible extension of the standard being downward compatible to the existing standard is sketched. The presentation concludes with a preliminary performance evaluation using goodput as a metric.

Revision History

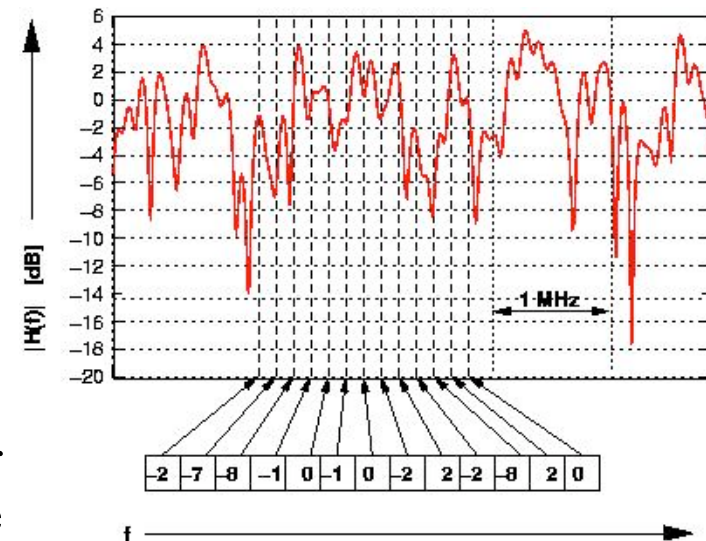
- R01** **Presented May 2007**
- R02** **Revised simulation results. Fixed problem with a single sub-carrier having a permanent SNR of 0 dB.**

Outline

- **Link Adaptation vs. Dynamic OFDM**
- **Dynamic OFDM Requirements**
- **Protocol Modifications for dynamic OFDM**
- **Performance Evaluation**
- **Conclusions**

Frequency-Selective OFDM Channel and Link Adaptation

- OFDM sub-carrier gains vary due to multi-path propagation environment
→ Always several sub-carriers are „in a bad state“
- OFDM-based 802.11 systems apply **link adaptation** in combination with fixed transmit power setting, i.e. each sub-carrier is modulated equally and receives the same transmit power.
- Applying link adaptation (as in 802.11a/g), i.e. modulating each sub-carrier with the same modulation type, is known to suffer from these varying sub-carrier gains as the BER is dominated by a few sub-carriers which are attenuated the most [Awoniyi06], [Gruenheid96] .



Dynamic OFDM for P2P Links

- If the transmitter knows sub-carrier gains, it can adapt the modulation type and transmit power individually per sub-carrier. Such schemes are generally known as **bit loading** schemes for OFDM systems.
- A special form is **adaptive modulation**: Fix the transmit power per sub-carrier but adapt the modulation type *subject to some target bit error probability*.
- It is well known that adaptive modulation improves the system performance of OFDM systems compared to link adaptation [Czylwik98].
- **How to incorporate Dynamic OFDM in 802.11a/g ?**
- **What is the performance of such a enhanced scheme accounting all the resulting protocol overhead?**

Dynamic OFDM in 802.11a/g

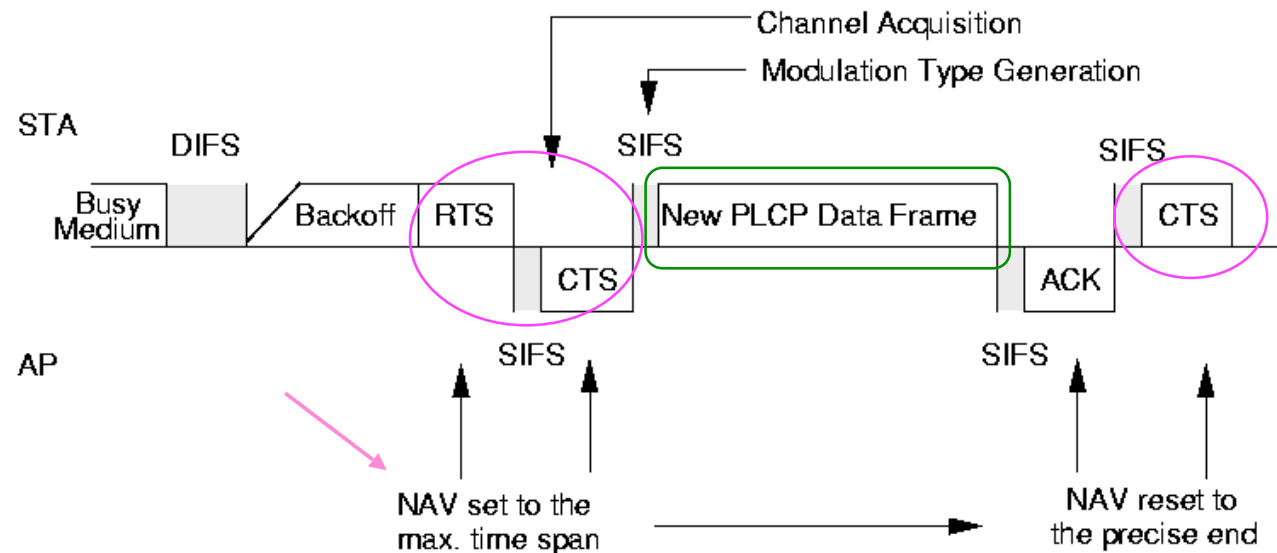
Requirement

- Channel knowledge at the transmitter
- Signaling of used modulation per sub-carrier from transmitter to receiver
- Computational resources at the transmitter

Followed approach

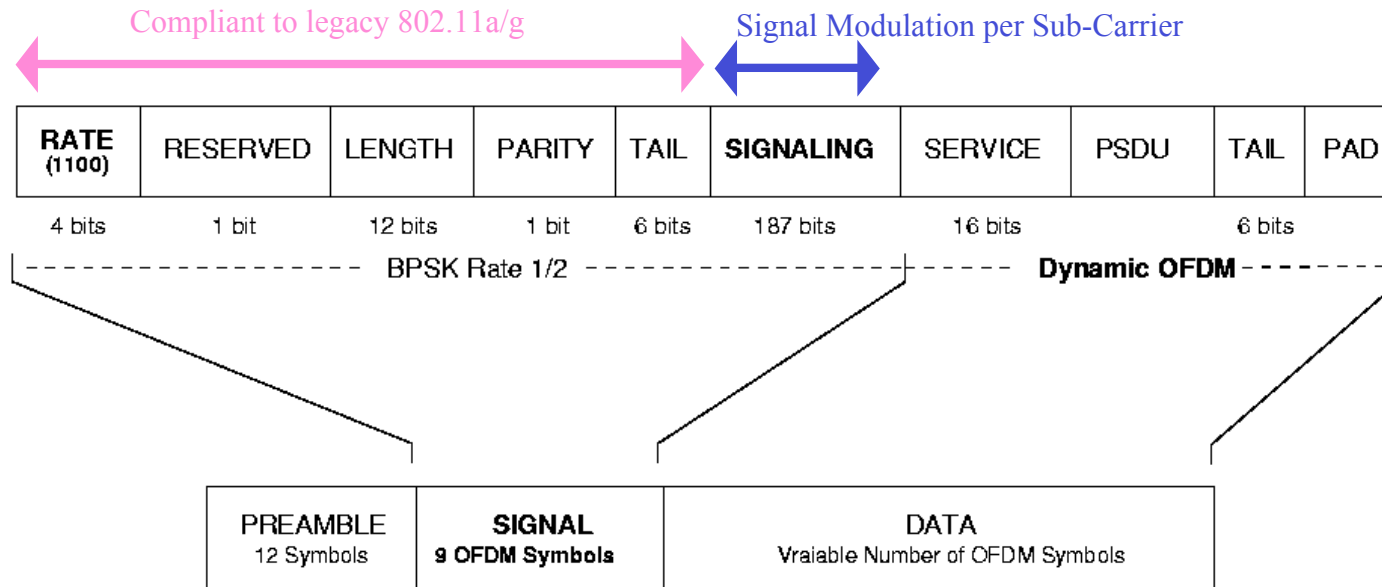
- Mandatory RTS/CTS for all transmissions
- Extend PPDU Header
- Not applicable to the standard (but shown to be achievable [LVESUK07])

Proposed Mandatory Transmission Sequence for Dynamic OFDM 802.11a/g Systems



- Why additional CTS-to-self ?
 - No channel knowledge at the transmission of RTS/CTS --> set NAV assuming „worst case modulation“ on all sub-carriers
 - Legacy STAs can't decode the body of the new PLCP Frame --> cannot obtain duration field and thus cannot reset NAV --> CTS-to-self resets NAV at all STAs in the vicinity of the transmitter.
- **Legacy 802.11a/g compliant transmission** except the new PLCP Frame

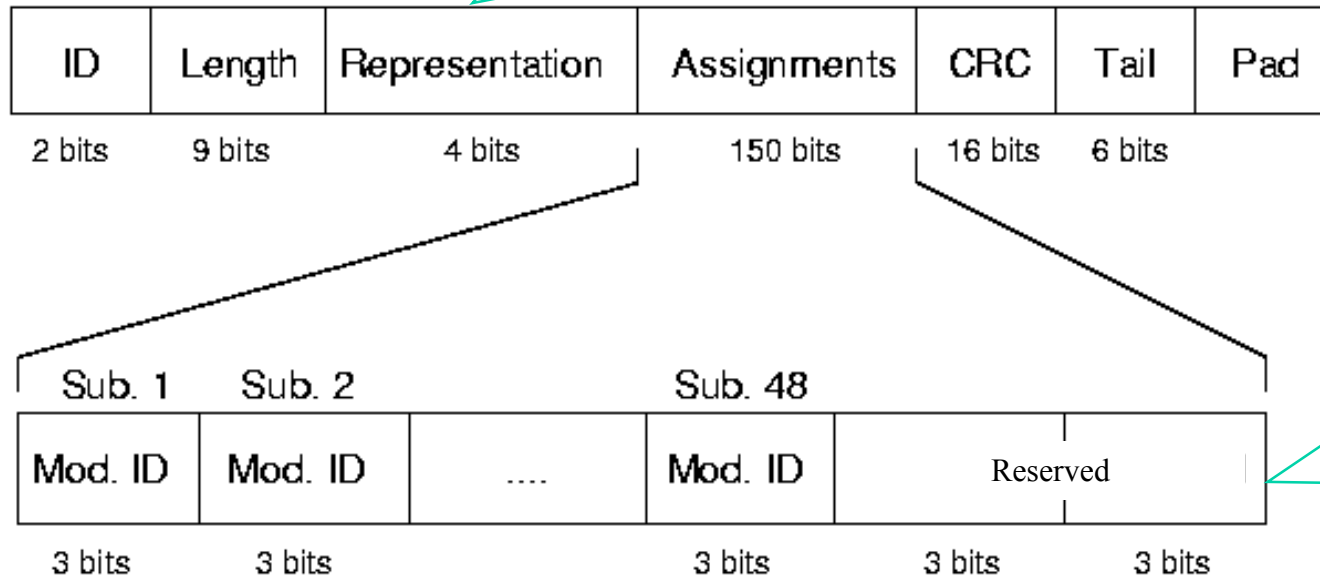
Proposed PPDU for Dynamic OFDM



- Both, modulation and fields at the beginning of new PPDU frame compliant to legacy 802.11a/g
 - **RATE** field indicates usage of Dynamic OFDM in DATA part of PPDU
 - --> legacy devices can decode the the RATE and LENGTH field and ignore the transmission if not capable of decoding Dynamic OFDM
- New “SIGNALING” field (per sub-carrier modulation information)

Proposed Signaling Field extending the OFDM PPDU to support Dyn. OFDM

Allow different representations, e.g. employing compression in the assignment

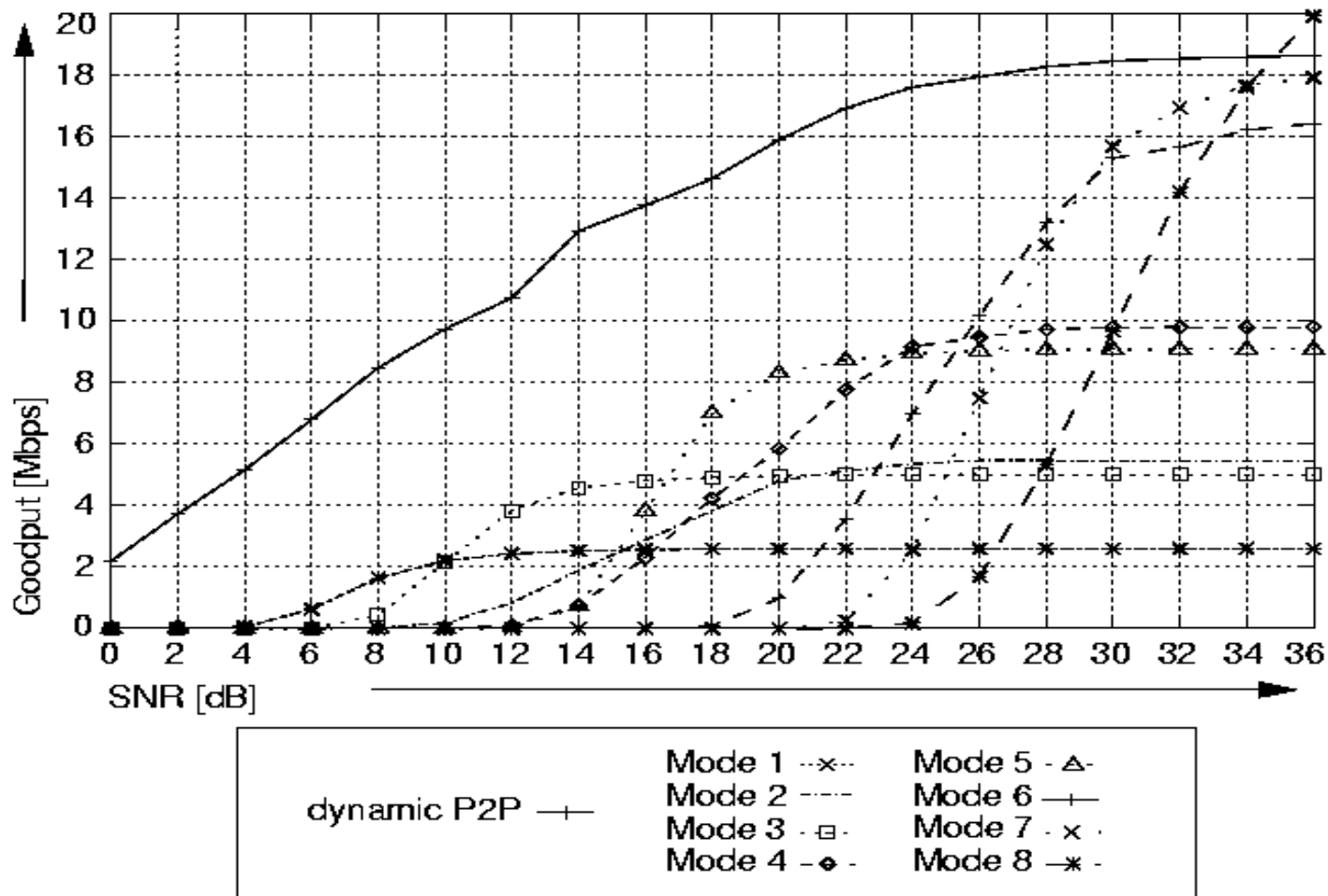


Assignment part as used throughout this evaluation

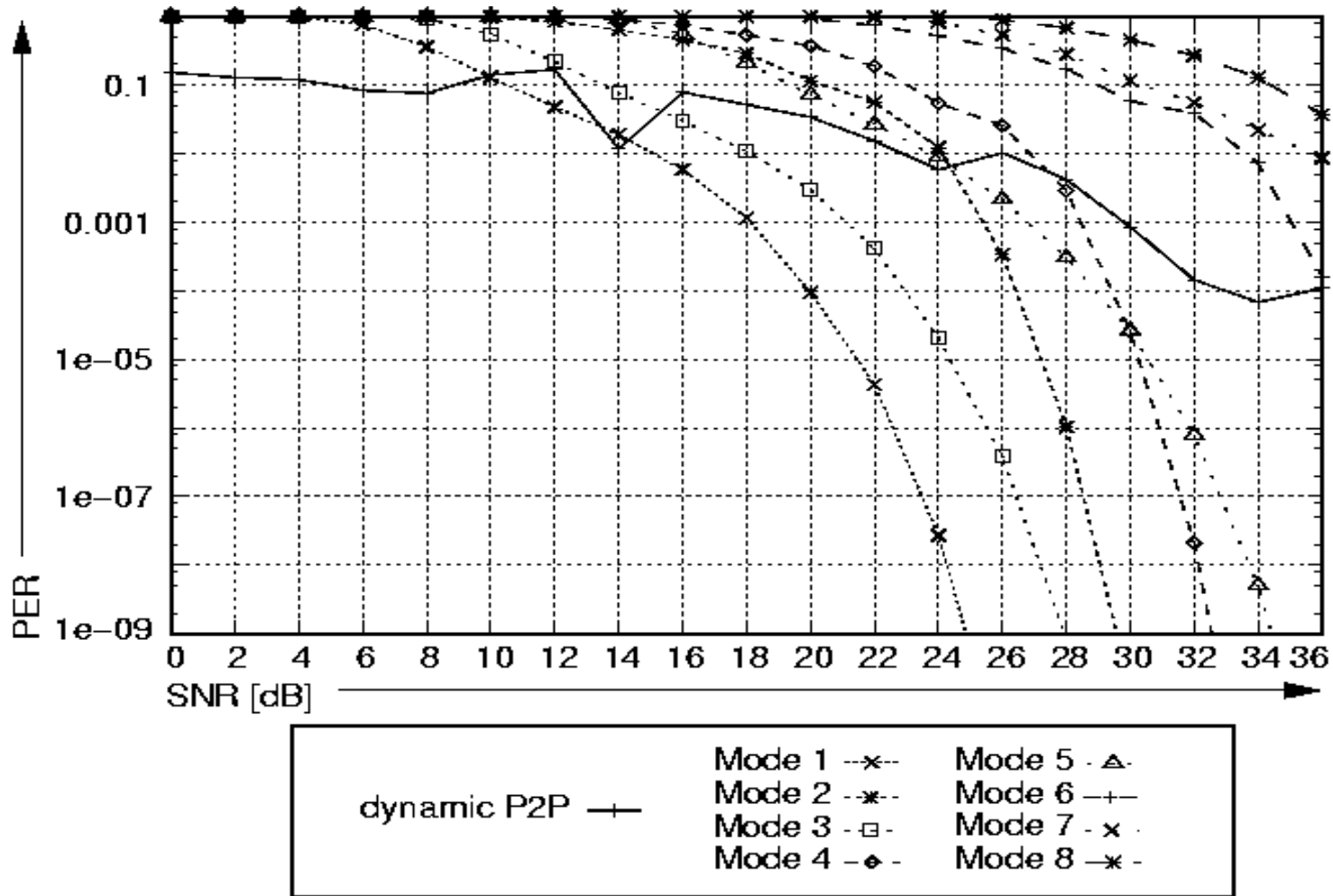
Performance Evaluation

- **Metric: Goodput**
- **Compare**
 - Dynamic OFDM with fixed transmit power and adaptive modulation
 - Legacy 802.11a without RTS/CTS
 - Legacy 802.11a with RTS/CTS handshake
- **Simulation**
 - Dynamic OFDM chooses modulation per sub-carrier to achieve the highest netto data rate (accepting a higher gross PERs)
 - Two packet sizes
 - Large packets, 1564 Bytes (file download)
 - Small packets, 228 Bytes (VoIP)
 - One Transmitter, one receiver (--> no collisions)
 - Simulation of the transmission of several thousand packets for a fixed average SNR with exponentially distributed fading
 - Simulator: OPNETmodeler/wireless

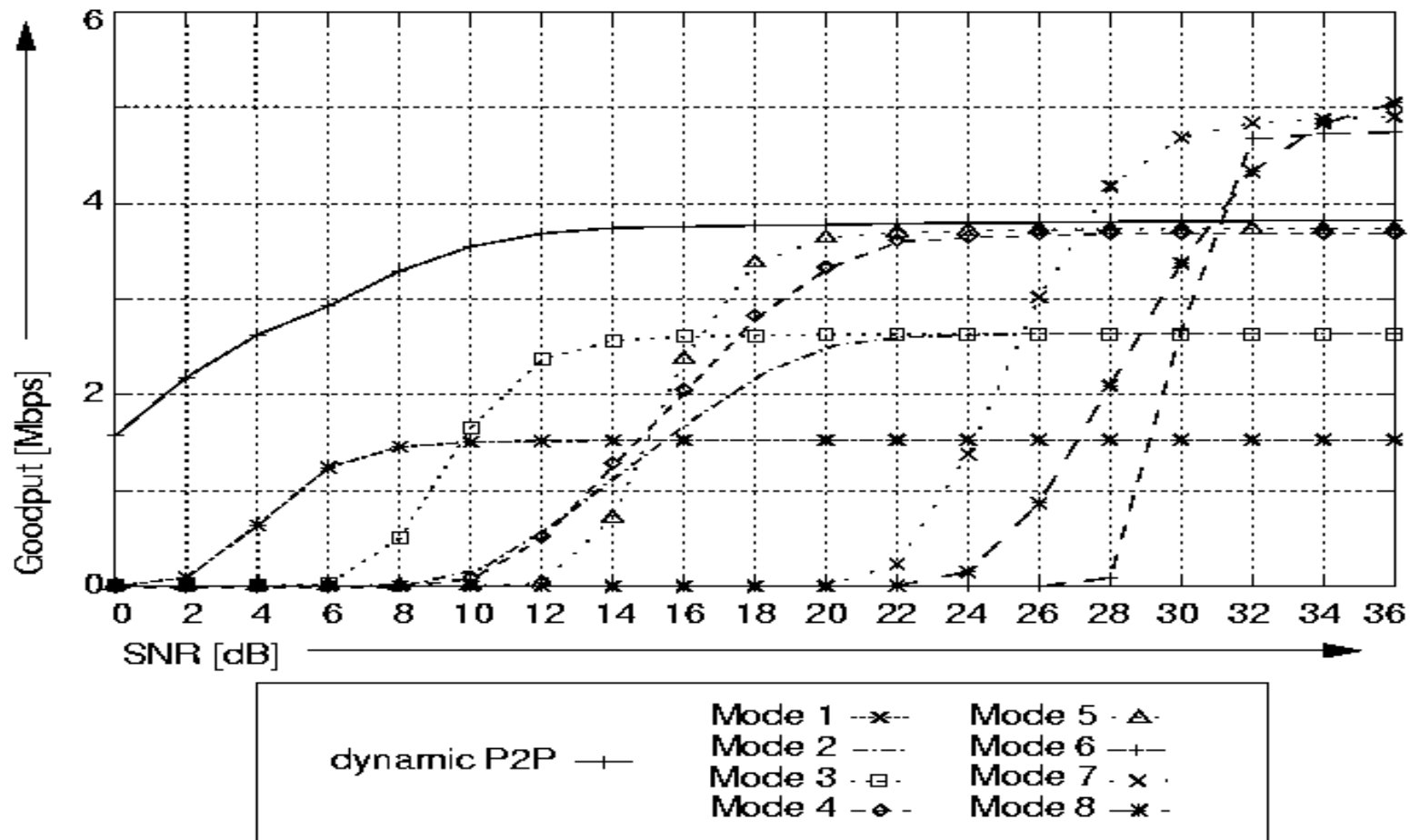
Goodput – Large Packets (1564 Byte) with RTS/CTS Handshake



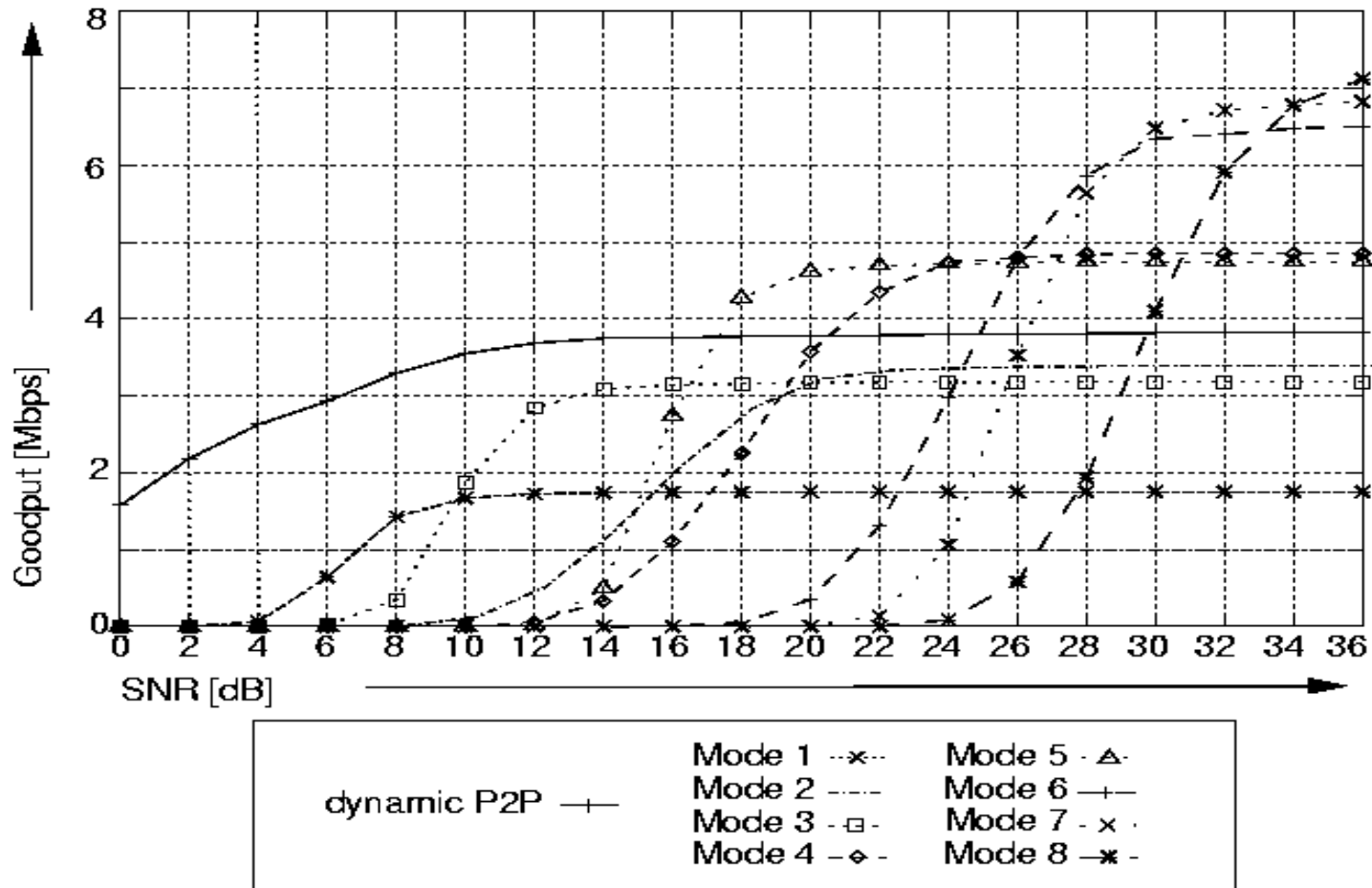
PER – Large Packets (1564 Byte)



Goodput – Small Packets (228 Byte) with RTS/CTS Handshake



Goodput – Small Packets (228 Byte) without RTS/CTS Handshake



Conclusions & Future Work

- **Significant performance gain for**
 - large packets at any considered SNR and even
 - for small at small and medium SNR
- **Much better control of bit error rate behavior in a frequency-selective OFDM system**
- **Moderate protocol overhead**
- **Some changes to the hardware required**

- **Evaluation with real channel data as future work**
- **Gauge how much Multi-User Dynamic OFDM can further increase the performance**

Further Results & Aspects

Technical Report

TKN-07-002

available at :

www.tkn.tu-berlin.de/publications/reports.jsp

Discussion

Thank you for your attention.



Questions -- Discussion
Suggestion for further evaluations

Straw Poll

**Should further work be presented to 802.11 WNG
including**

- additional simulation results of the just seen point-to-point and
- multi-user

**dynamic OFDM transmissions employing an extended
802.11a/g?**

Yes: 8

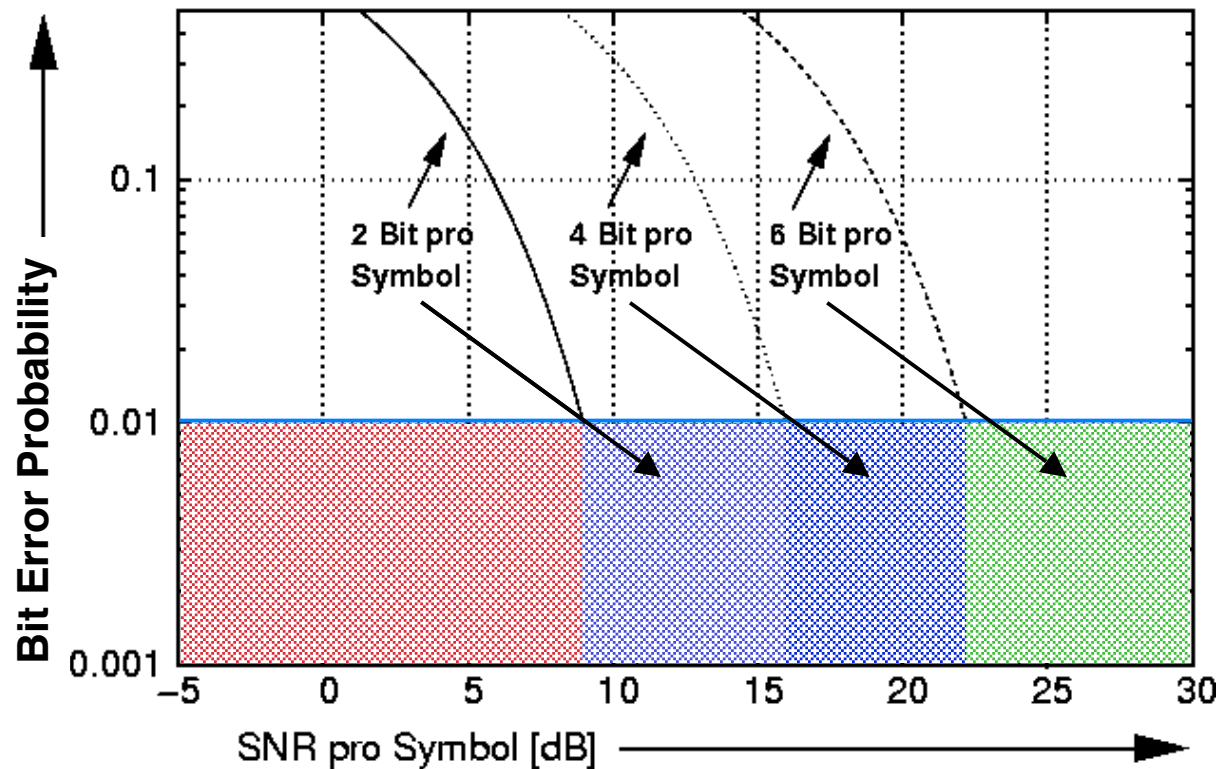
No: 3

References

- [Awoniyi06] O. Awoniyi, F. Tobagi, "Packet Error Rate in OFDM-based Wireless LANs Operating in Frequency Selective Channels", Proc. *IEEE Infocom 2006*.
- [Gruenheid96] H. Rohling, R. Gruenheid, „Performance of an OFDM-TDMA Mobile Communication System“, Proc. *IEEE VTC 1996*.
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- [LVESUK07] Hermann S. Lichte, S. Valentin, Falk Eitzen, Matthias Stege, Carsten Unger, and H. Karl, "Integrating multiuser dynamic OFDMA into IEEE 802.11a and prototyping it on a real-time software-defined radio testbed" *To appear In Proc. Intl. Conf. on Testbeds and Research Infrastructures for the Development of Networks and Communities (TridentCom)*, May 2007.

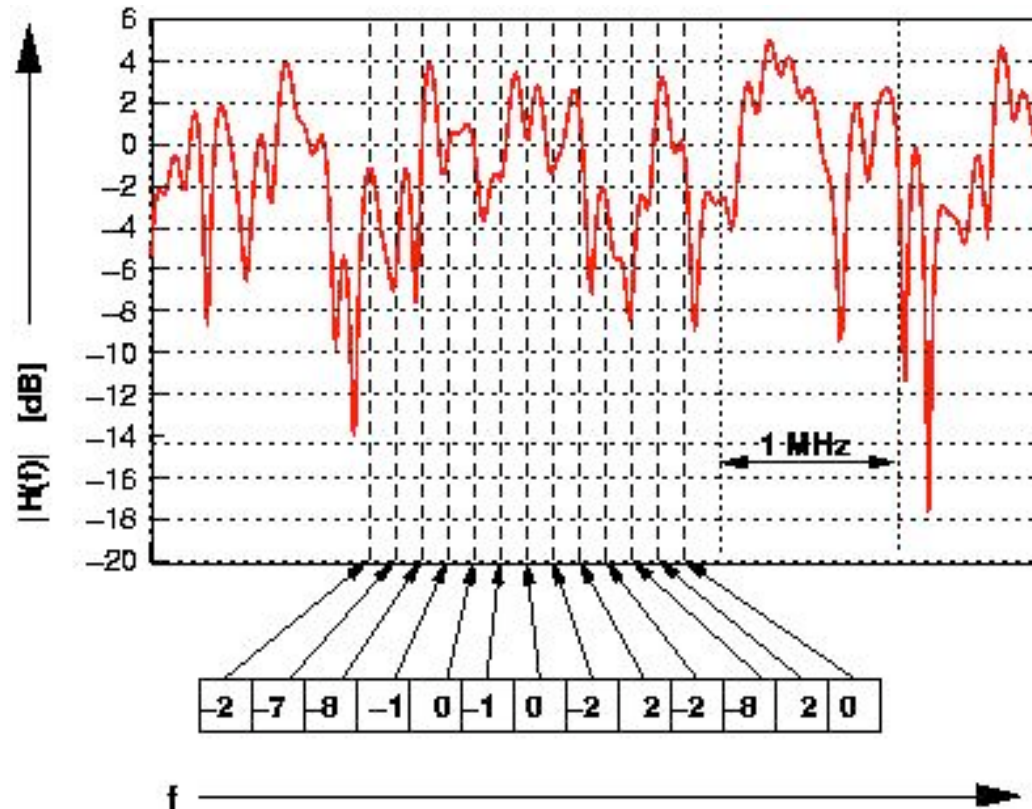
BACKUP SLIDES

Adaptive Modulation per Sub-carrier



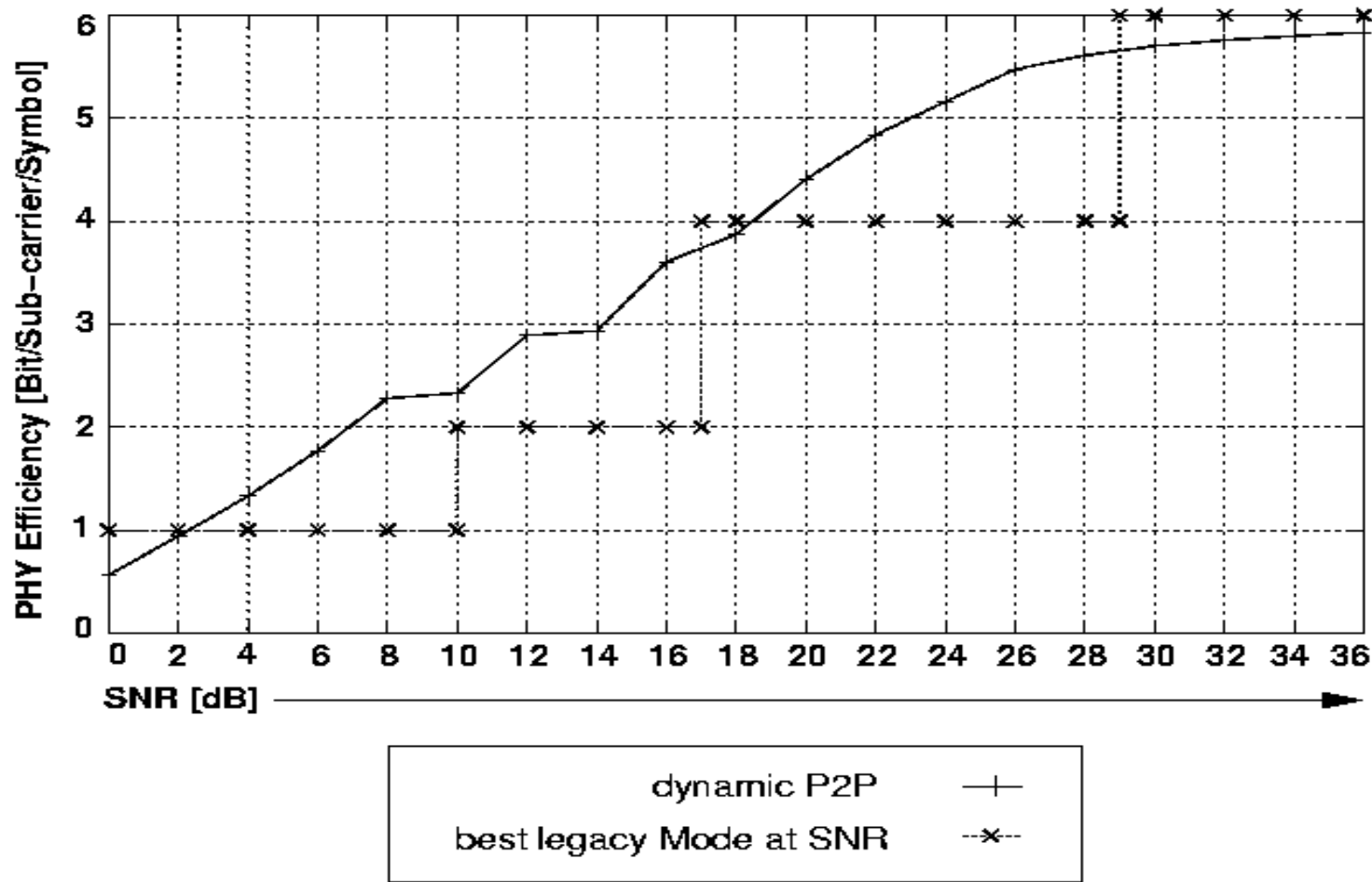
Adaptive Modulation partitions the SNR into several regions where some modulation type (i.e. BPSK, QPSK, 16-QAM, 64-QAM) are exclusively applied. The „switching points“ of the modulation types are governed by the target bit error probability. The higher the target BER, the less SNR is required to apply a certain modulation type.

Link Adaption in OFDM



Applying a fixed modulation type and transmit power leads to a strongly varying BER of the link, dominated by the „few“ sub-carriers which are attenuated most!

PHY Modulation Efficiency large Packet (1564 Byte)



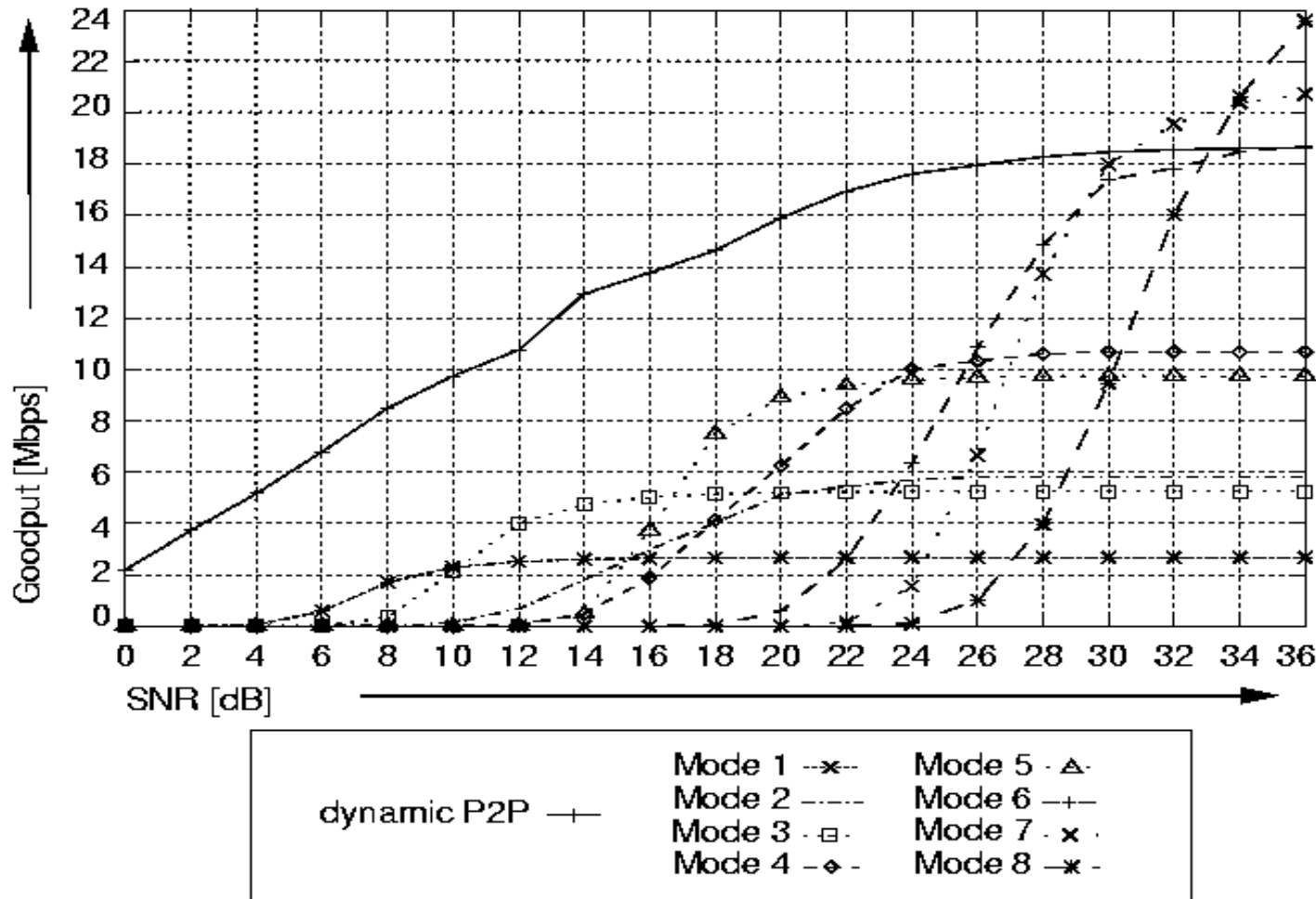
802.11a OFDM PHY Modulation Modes

Table 135—Modulation-dependent parameters

Modulation	Coding rate (R)	Coded bits per subcarrier (N_{BPSK})	Coded bits per OFDM symbol (N_{CBPS})	Data bits per OFDM symbol (N_{DBPS})	Data rate (Mb/s) (20 MHz channel spacing)	Data rate (Mb/s) (10 MHz channel spacing)	Data rate (Mb/s) (5 MHz channel spacing)
BPSK	1/2	1	48	24	6	3	1.5
BPSK	3/4	1	48	36	9	4.5	2.25
QPSK	1/2	2	96	48	12	6	3
QPSK	3/4	2	96	72	18	9	4.5
16-QAM	1/2	4	192	96	24	12	6
16-QAM	3/4	4	192	144	36	18	9
64-QAM	2/3	6	288	192	48	24	12
64-QAM	3/4	6	288	216	54	27	13.5

Source: 802.11REVma/D9.0

Goodput – Large Packets (1564 Byte) without RTS/CTS Handshake



PER – Small Packets (228 Byte)

