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

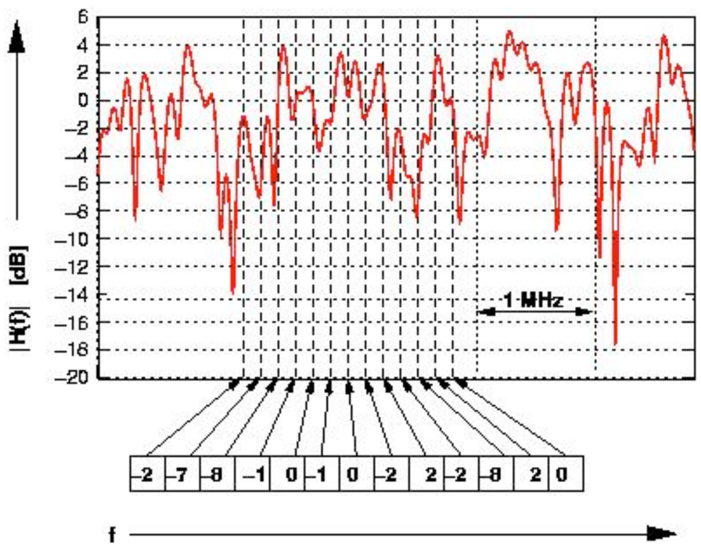
R01	**Presented May 2007**
R02	**Revised simulation results. Fixed problem with a single sub-carrier having a permanent SNR of 0 dB.**

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].

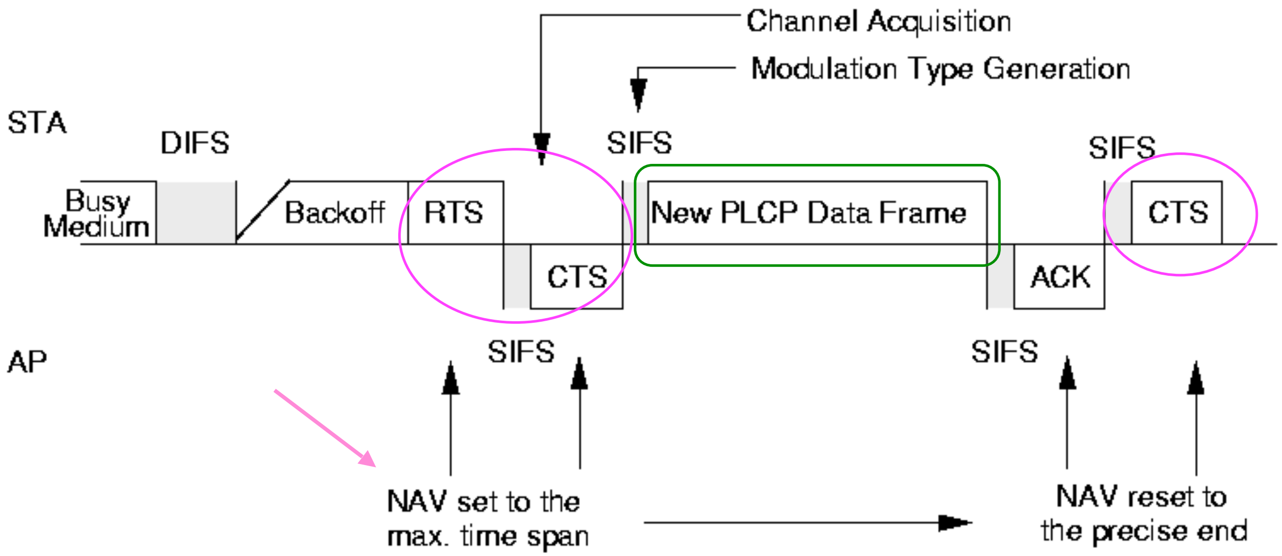
- **How to incorporate Dynamic OFDM in 802.11a/g ?**

- **What is the performance of such a enhanced scheme accounting all the resulting protocol overhead?**

Dynamic OFDM in 802.11a/g

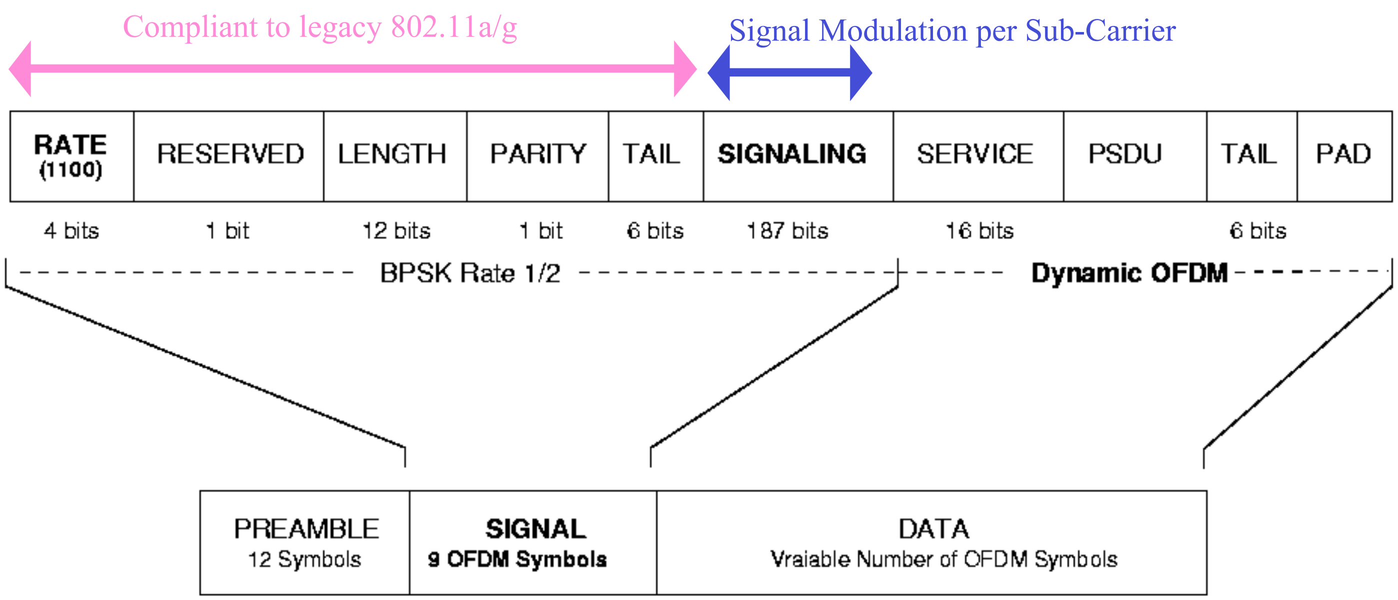
Requirement	Followed approach
– Channel knowledge at the transmitter	– Mandatory RTS/CTS for all transmissions
– Signaling of used modulation per sub-carrier from transmitter to receiver	– Extend PPDU Header
– Computational resources at the transmitter	– Not applicable to the standard (but shown to be achievable [LVESUK07])

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



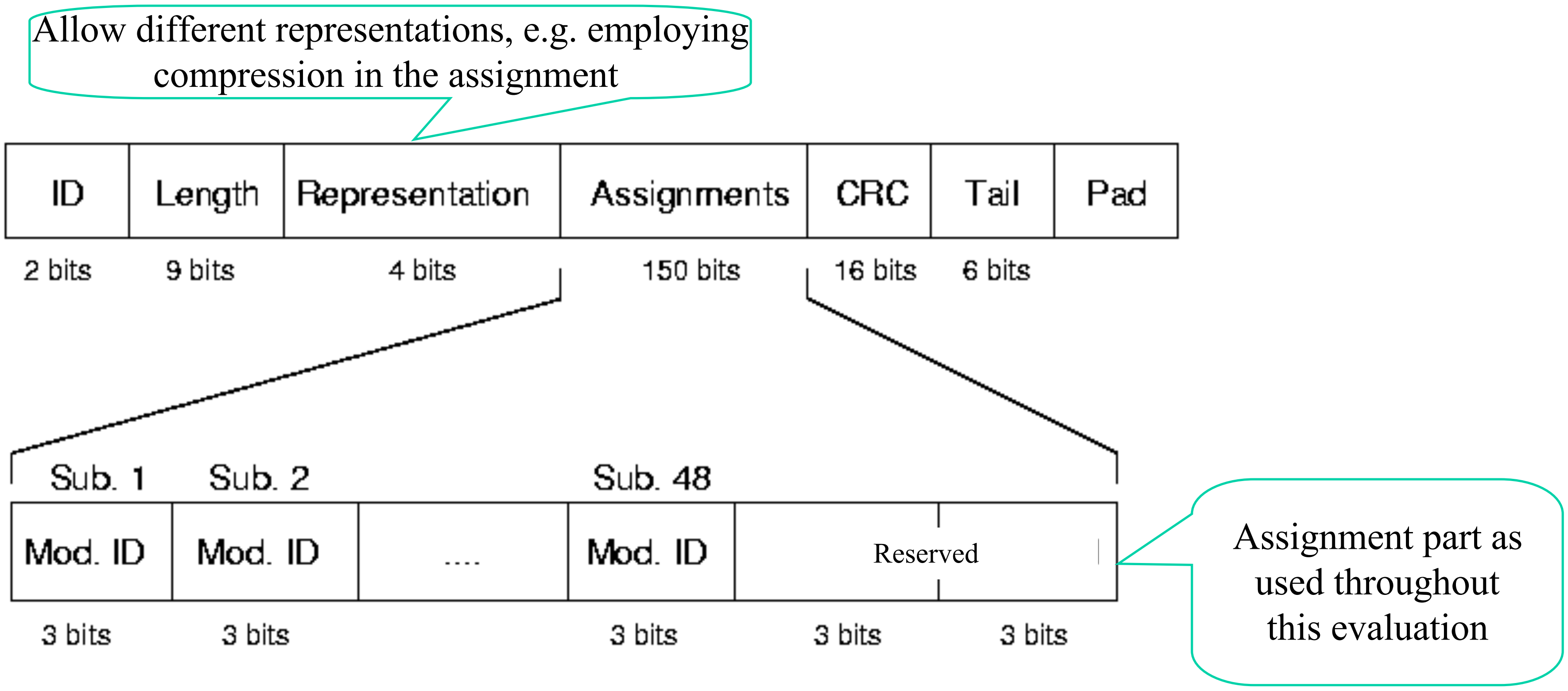
- Why additional CTS-to-self ?
  - No channel knowledge at the transmission of RTS/CTS --> set NAV assuming „worst case modulation“ on all sub-carriers
  - Legacy STAs can‘t decode the body of the new PLCP Frame --> cannot obtain duration field and thus cannot reset NAV --> CTS-to-self resets NAV at 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)

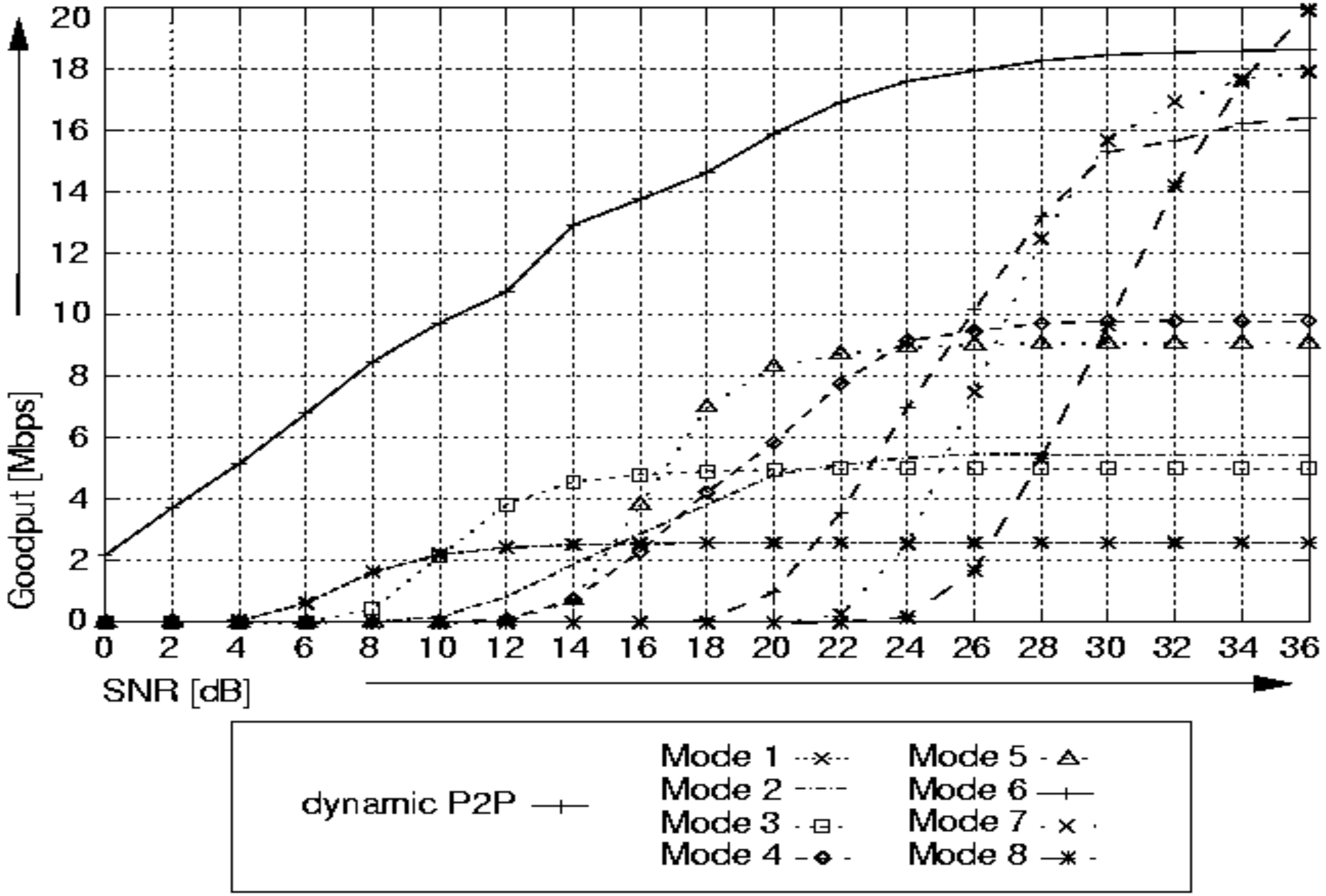
Proposed Signaling Field extending the OFDM PPDU to support Dyn. OFDM



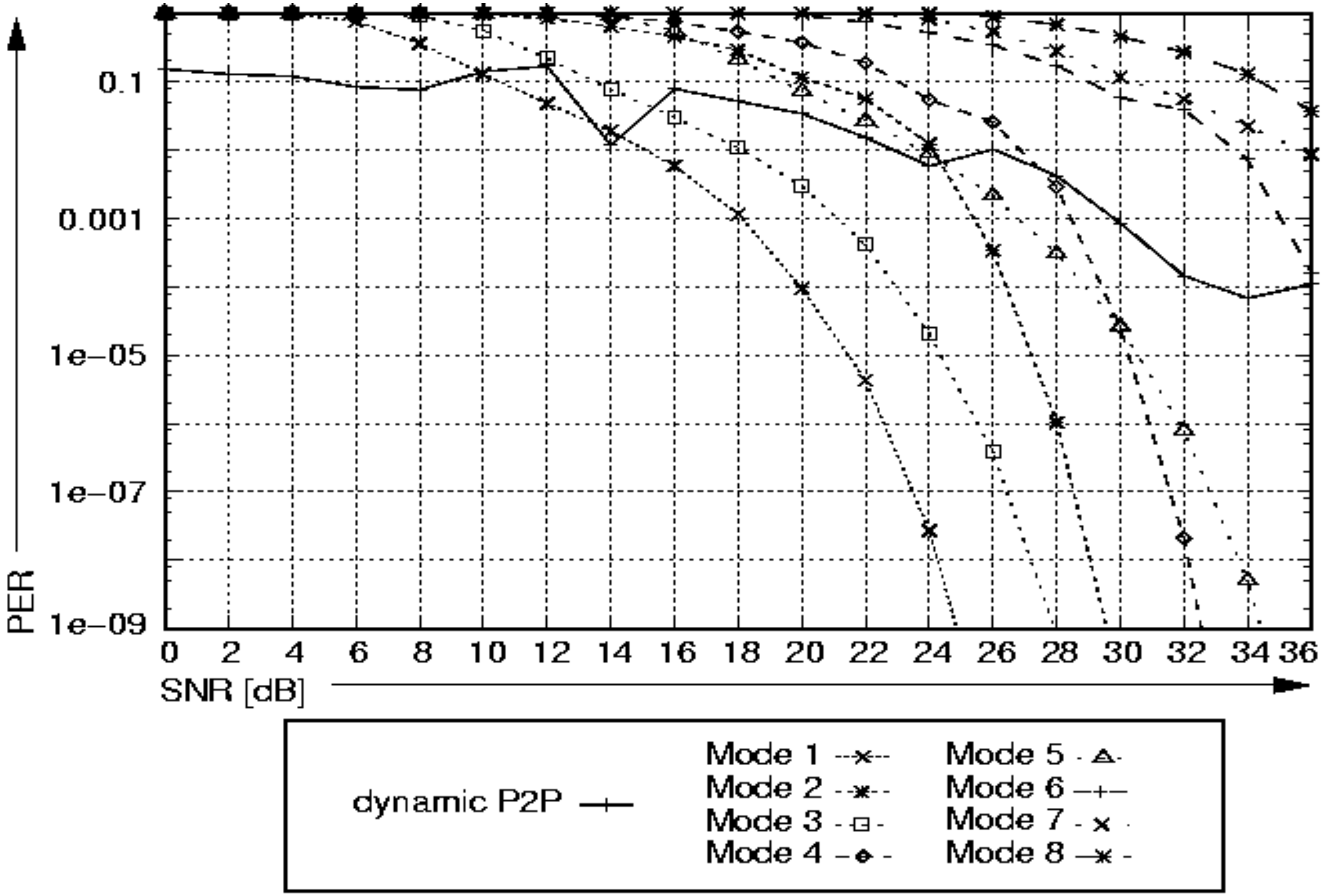
Performance Evaluation

- **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

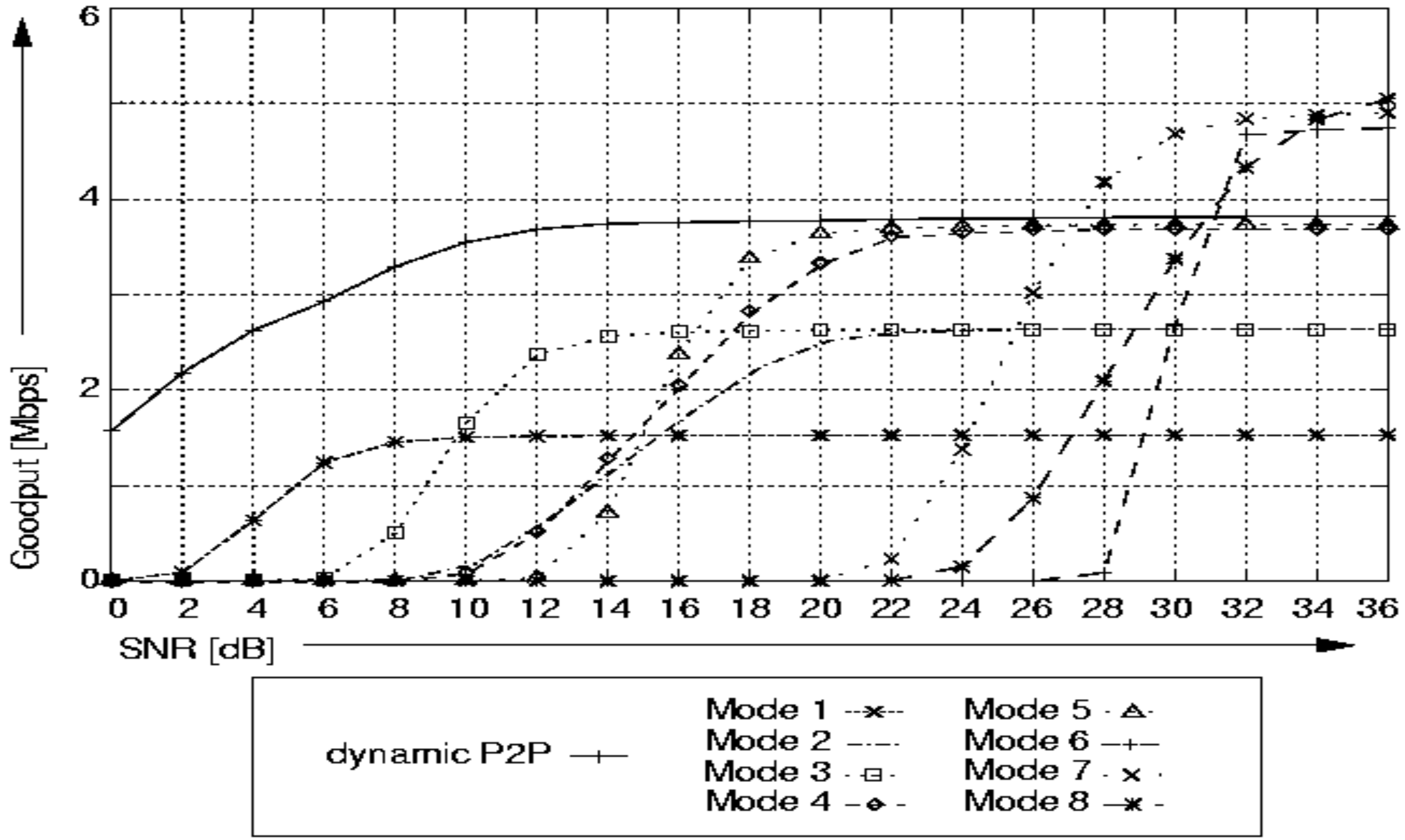
Goodput – Large Packets (1564 Byte) with RTS/CTS Handshake



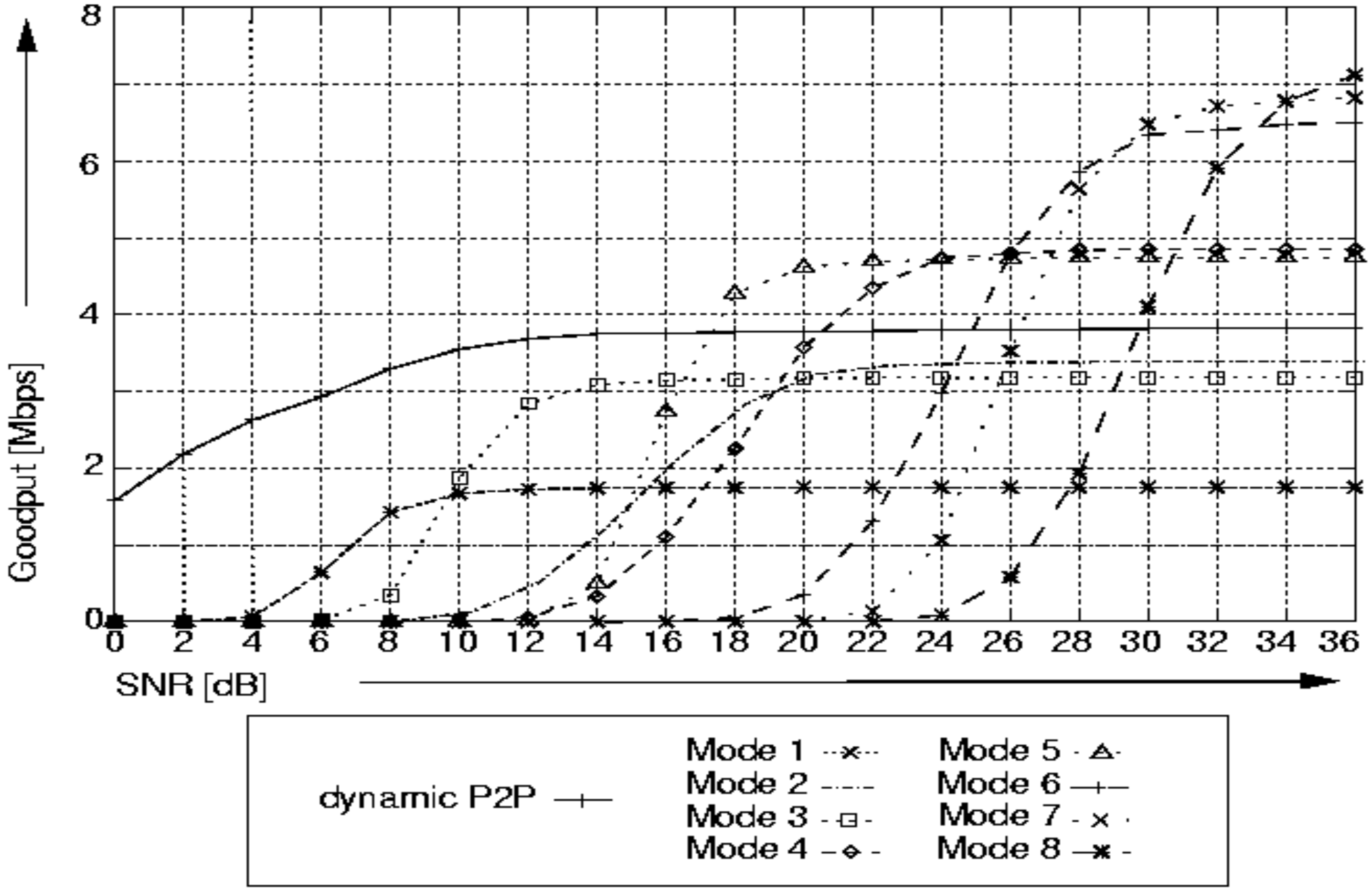
PER – Large Packets (1564 Byte)



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*.

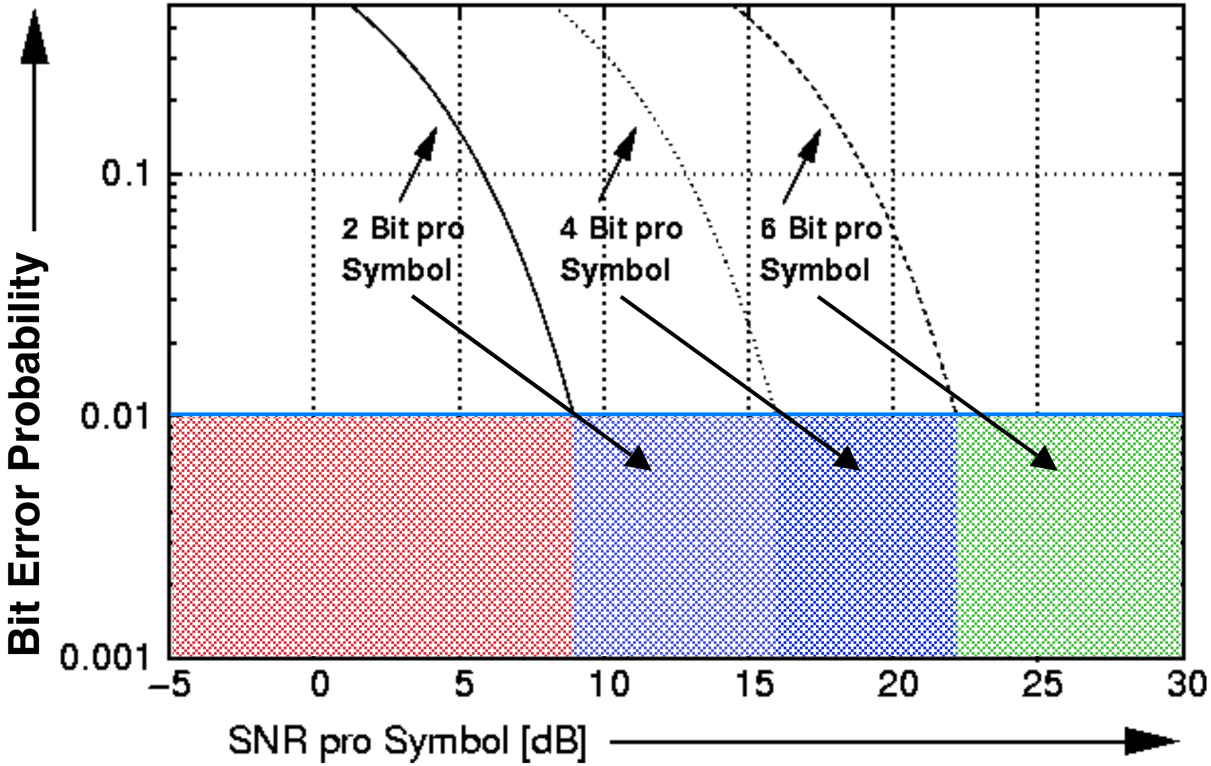
[Gruenheid96] H. Rohling, R. Gruenheid, „Performance of an OFDM-TDMA Mobile Communication System", Proc. *IEEE VTC 1996*.

[Czylwik98] A. Czylwik, "OFDM and Related Methods for Broadband Mobile Radio Channels", Proc. *Inter. Zürich Seminar on Broadband Communications 1998*.

[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.

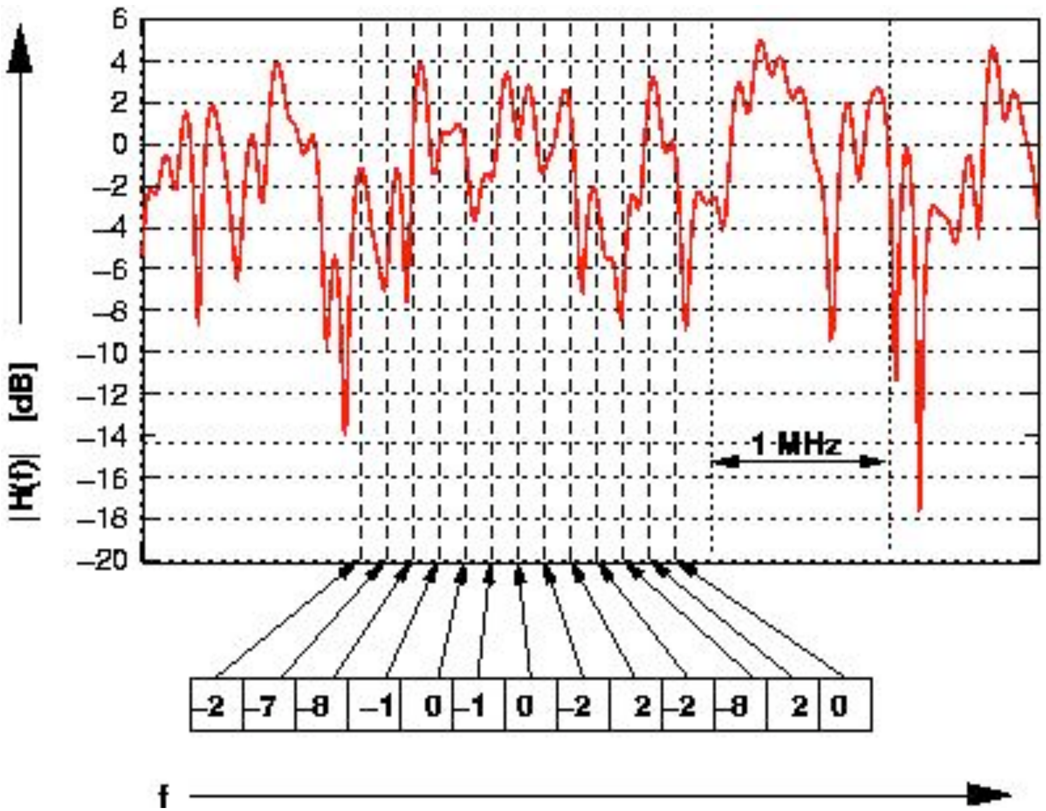
BACKUP SLIDES

Adaptive Modulation per Sub-carrier



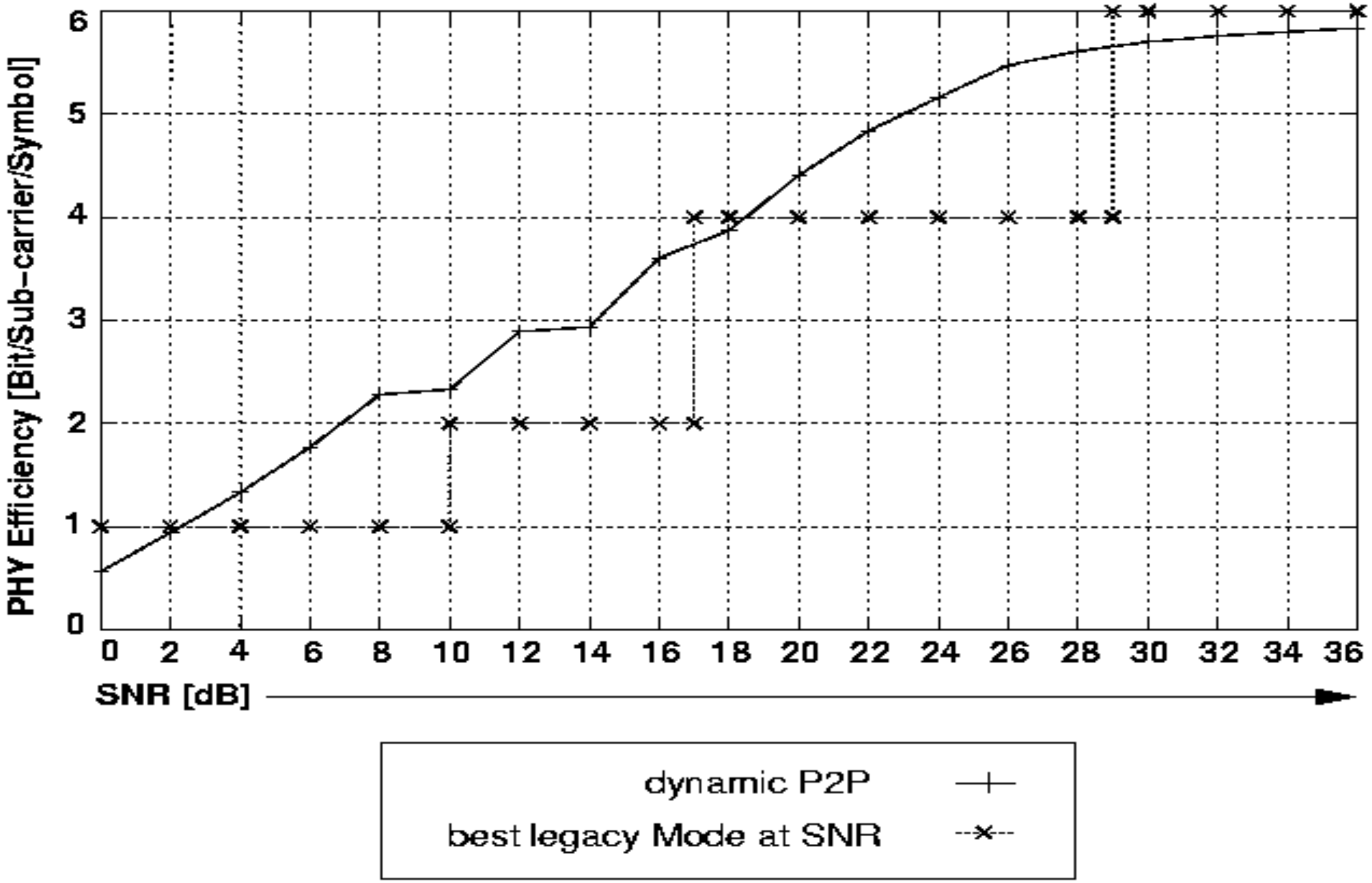
Adaptive Modulation partitions the SNR into several regions where some modulation type (i.e. BPSK, QPSK, 16-QAM, 64-QAM) are exclusively applied. The „switching points" of the modulation types are governed by the target bit error probability. The higher the target BER, the less SNR is required to apply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



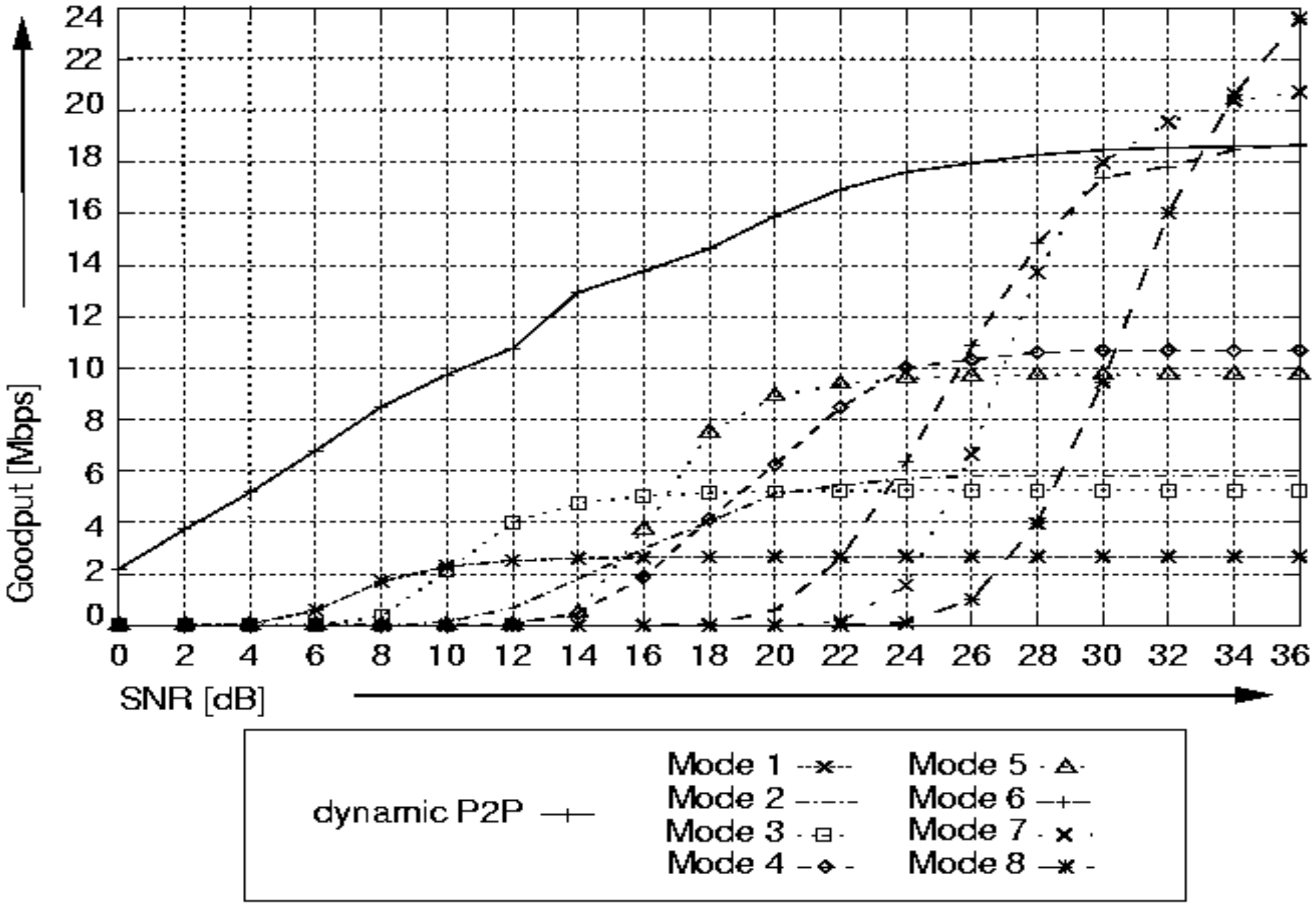
802.11a OFDM PHY Modulation Modes

Table 135—Modulation-dependent parameters

Modulation	Coding rate (R)	Coded bits per subcarrier (N_{BPSC})	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)