Paper submitted to

10^{th} Aachen Symposium on Signal Theory

Name:	Andreas Krämling
Affiliation:	Communication Networks Aachen University of Technology
Address:	Kopernikusstr. 16 D–52074 Aachen, Germany
Phone:	+49 241 80 7911
Fax.:	+49 241 88 88242
E-mail:	akr@comnets.rwth-aachen.de

Paper Title:	A Power Control Strategy for HIPERLAN/2
Symposium Topic:	Quality of Service Control
Characterizing Keywords:	Hiperlan/2, Power Control, Link Adaptation
WWW:	http://www.comnets.rwth-aachen.de/~akr
Number of Pages:	7

A Power Control Strategy for HIPERLAN/2

Andreas Krämling

Communication Networks
Aachen University of Technology
Kopernikusstr. 16
D–52074 Aachen, Germany
Phone: +49 241 80 7911
E-mail: akr@comnets.rwth-aachen.de

Abstract

Modern mobile communication systems like HIPERLAN/2 (HIgh PEformance Radio Local Area Network) offer power control (PC) and link adaptation (LA) to adjust the transmission to the current channel conditions. The physical layer of HIPERLAN/2 offers seven PHY-Modes providing a data rate between 6 Mbit/s and 54 Mbit/s. Thus, the capacity available to an AP depends on the interference situation of the selected channels. LA and PC has influence on the interference situation in neighbour cell and the available data rate, since less interference allows to use PHY-Modes leading to higher data rate. In this paper an approach for power control in HiperLAN/2 networks is presented which uses this circumstance to *exchange* transmission capacity between APs in a simply to realise but efficient way.

1 Introduction

During the last years the bandwidth requirements of private networks have been drastically increased. Mobile communication is getting more and more popular. Future wireless systems will not only allow voice communication but also support multimedia traffic. During the last years HIPERLAN/2 (H/2) was standardised by the ETSI Project Broadband Radio Access Network (BRAN). H/2 was specially designed to support the Quality of Service (QoS) requirements of different traffic types. It supports different kinds of core networks like Ethernet (IEEE 802.3), IP and Firewire (IEEE 1394). To be able to guarantee the QoS requirements of established connections, capacity is assigned to the mobile terminals (MT) by a central instance, the access point (AP).

H/2 networks are operating in the unlicensed 5 GHz band. To adapt the transmission to the channel conditions seven combinations (PHY-Mode) of modulation and coding are available offering data rates between 6 Mbit/s and 54 Mbit/s per AP. Link Adaptation (LA) is used to select a PHY-Mode according to the channel condition and the requirements of the connection. Power control can be used to control the power consumption of the mobile device and to adjust the level of the received signal. In this paper a strategy for power control is introduced which provides in combination with LA a kind of dynamic capacity assignment to AP.

After a short introduction into the medium access control part of H/2 an introduction into the aspects of LA and PC is given. Afterwards the a combined strategy for LA and PC is introduced and evaluated by simulations.

2 HIPERLAN/2

The Medium Access Control (MAC) protocol applies a centralised controlled concept. The AP assigns the radio resources in terms of packets for both the uplink and the downlink phase to the individual MTs dynamically. It thus is a load adaptive TDMA/TDD (Time Division Multiple Access/Time Division Duplex) scheme. A MAC-Frame has a constant length of 2 ms. The assignment of resources to the individual MTs and their connections is not static but may change dynamically from one MAC-Frame to the other. The basic structure of a MAC-Frame and the phases it consists of are shown in Fig. 1.

Broadcast Phase (BC): the BC phase carries the

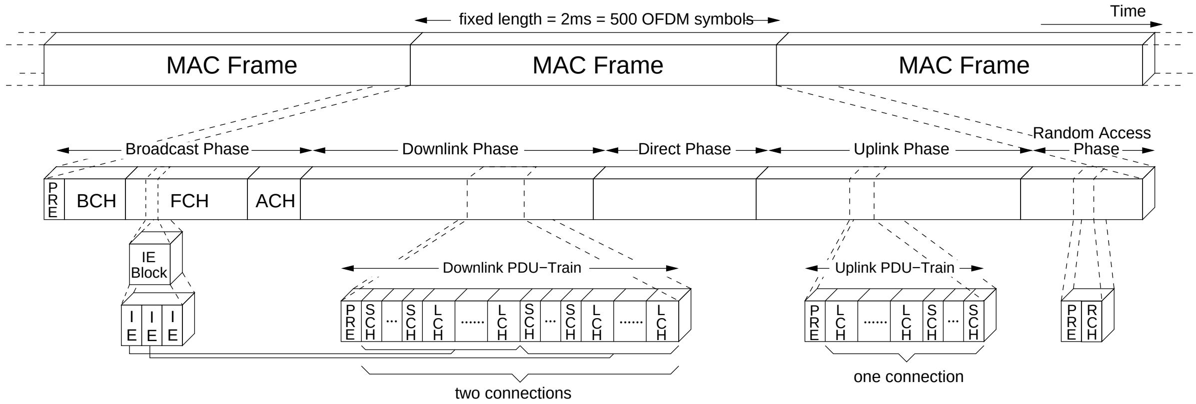

Figure 1: H/2 MAC-Frame

Broadcast Control Channel (BCCH) and the Frame Control Channel (FCCH). The BCCH contains general announcements. The FCCH carries information about the structure of the upcoming frame.

Downlink phase (DL): The DL phase carries user specific control information and the user data, transmitted from the AP to the MTs. To the terminals Long Transport Channels (LCHs) and Short Transport Channels (SCHs) are assigned. The SCHs are mainly used to transmit signalling information while LCHs carry mainly user data.

Uplink Phase (UL): The UL phase carries control and user data from the MTs to the AP.

Random Access Phase (RA) MTs that do not have capacity allocated in the Uplink phase can use the RA phase for transmission of control information. Non-associated MTs get in first contact with an AP via the Random Access Channel (RACH). This phase is also used by MTs performing handover to have their connections switched over to a new AP. For the RA phase the principle of the slotted ALOHA algorithm with a binary exponential back-off strategy is applied

Each of these phases contain logical channels that are mapped on physical transport channels. In order to save capacity, all PDUs belonging to the same MT are combined to so called PDU-trains. This is done for the up- as well as for the downlink. Thus, only one preamble per MT is necessary for synchronization reasons. For further details on the MAC layer see [1].

3 Link Adaptation and Power Control

H/2 offers Link Adaptation (LA) and Power Control (PC) to adapt the transmission to the channel quality

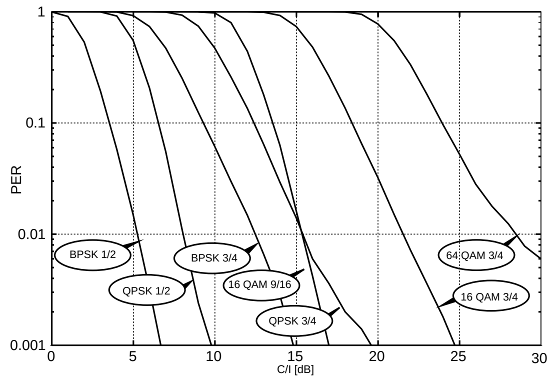

Figure 2: PHY-Modes

[1, 2]. The H/2 physical layer offers 6 different combinations of modulation and coding schemes resulting in a data rate from 6 Mbit/s to 54 Mbit/s (cf. Fig. 2). Based on the transmission quality (PER/CIR) the AP selects a suitable PHY-Mode according to the requirements of the connections. The selection of an appropriate PHY-Mode is based on the status (PER/CIR) of received packets which is used to predict the future channel conditions [3]. The switching points where to change from one PHY-Mode to an other can be used to optimise the LA on throughput or PER. A lower PER is e.g. required for time critical services to avoid additional delay resulting from retransmissions. For data services (e.g. FTP) the LA is optimised on throughput. The PHY-Mode to be used for a connection is announced within the FCH and can be changed from frame to frame. The usability of a certain PHY-Mode is also influenced by the transmission power of the sender. A higher transmission power increases the CIR and enables the AP to use higher PHY-Modes resulting in a higher data rate. On the other side a higher transmission power increases the interference in the neighbour cells.

Thus, it is important to develop a strategy which considers the aspects of LA and PC to achieve an optimum solution.

3.1 Strategy for Power Control

What should be the goal of a PC strategy? It must be considered that H/2 is working in an unlicensed frequency band and that H/2 systems of different manufactures might operate in the same area. Since the LA/PC algorithm is an implementation specific issue each manufacturer wants to ensure that the traffic handled by *his* equipment is served in a most efficient way. Therefore, the PC algorithm should not influence the transmission of own packets (e.g. increase delay or PER). Nevertheless, the generated interference can be reduced as much as possible. In the following an easy and efficient strategy is introduced which fulfills these requirements.

In H/2 the MAC Frames are used to organise the access on the the shared physical medium. Using the maximum transmission power usually results in a data rate that is higher than the required one. Thus, the MAC-Frame is only partly filled. In [4] different strategies are discussed to distribute the *unused* parts within the MAC-Frame. Nevertheless, the intensity of the interference changes significantly within the MAC-Frame, which makes the selection of the PHY-Mode more difficult. Thus, the generated interference should be distributed as homogeneous within the MAC Frame as possible.

A combination of LA and PC can be used to reduce the *unused* parts of the MAC-Frame: as long as the MAC-Frame is not completely filled, the transmission power and the PHY-Mode is reduced. If more capacity is required than provide by a MAC-Frame (not all LCH packets can be transmitted), the transmission power is increased again so that a higher PHY-Mode can be used, resulting in a higher data rate.

Since a larger part of the MAC-Frame is used, the interference situation becomes more steadier. Furthermore, the combination of PC and LA enables a kind of *dynamic capacity assignment* between APs. APs with less traffic generate less interference and allow other APs to use a higher PHY-Mode with a higher data rate.

3.2 Terminal Selection

An open point is the selection of the MTs of which the transmission power is adapted. To achieve the lowest possible interference in neighbour cells the transmission power at the cell border should be reduced first. Terminals in the center of the cell can use a higher transmission power since the attenuation towards stations in co-channel cells is higher. At the cell border more robust PHY-Modes usually must be used which offer a smaller range for power control. With regard to adjacent channel interference it is aimed to equalise the transmission power within the radio cell.

The selection of a suitable terminal must also consider the minimum interval between two power adjustments.

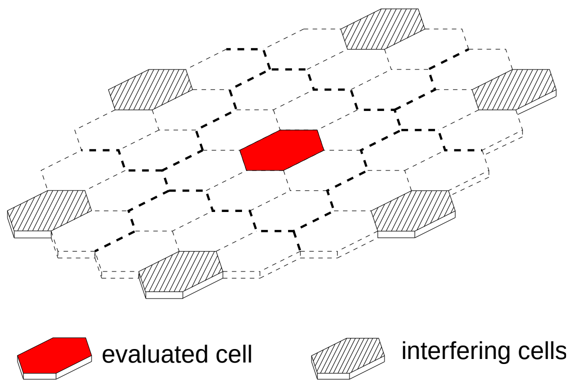

Figure 3: Evaluated Scenario (Cluster size 9)

To increase the data rate (and the transmission power) the selection is based on the following steps:

1. Only terminals that do not already use the highest PHY-Mode are considered
2. Power adjustment is possible (more then 20ms since last update passed)
3. Terminal with longest queue of waiting LCH packets
4. Terminal with lowest transmission power

If the MAC-Frame is not completely filled and the data rate (and the transmission power) should be reduced the terminal is selected as follows:

1. Only terminals that do not already use the lowest PHY-Mode
2. Power adjustment is possible (more then 20ms since last update passed)
3. Terminal with highest transmission power

4 Simulation Environment

To evaluate the PC/LA strategy a simple scenario consisting of one center cell and six co-channel cells is used (cluster size 9; cf. Fig. 3). Only the center cell is evaluated. The APs are located in the center of the cells. In each cell 500 terminals were uniformly distributed. Each MT is modeled as a two state machine. During the active state terminal's traffic source generates LCH packets using a Poisson arrival process with a mean equally distributed between L_{min} and L_{max}, while during the passive state no packets were generated at all. The duration of the on/off state is negative exponential distributed with a mean of 2 s and 48 s, respectively. In average 10 MTs were active; the distribution is shown Fig. 4.

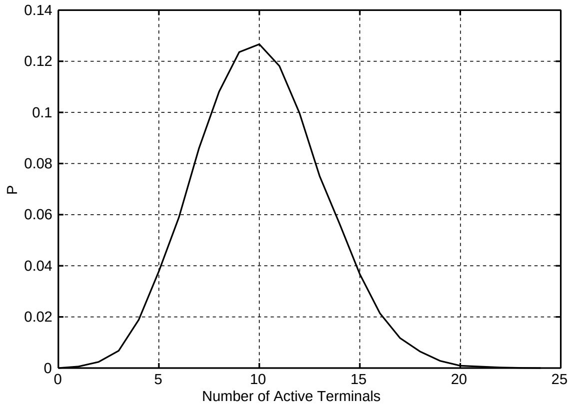

Figure 4: Number of Terminals

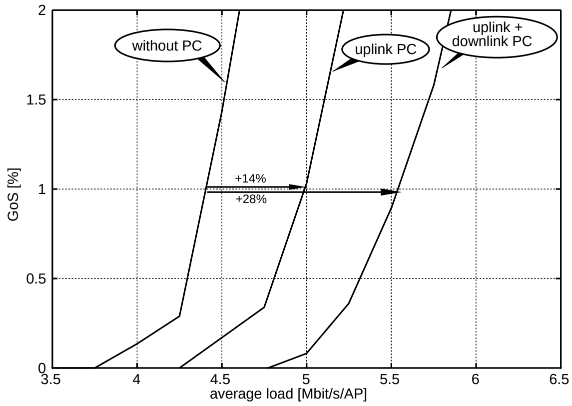

Figure 5: Grade of Service

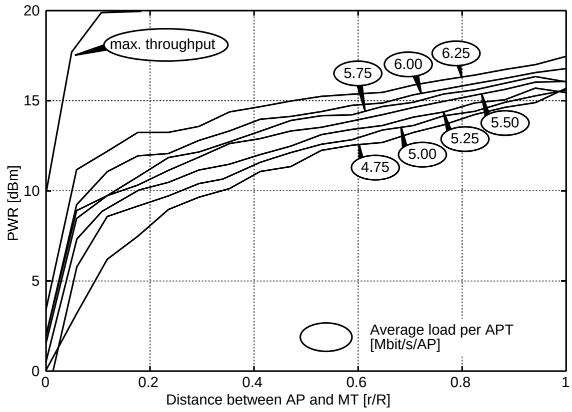

Figure 6: Influence of the Load on the Transmission Power

It is assumed that all APs/MTs were equipped with omni-directional antennas with no additional antenna gain. The pathloss is calculated by the following formula:

$$L = -46 + 24 log_{10} D \tag{1}$$

where D is the distance between sender and receiver. The CIR is calculated for each slot with all sending stations. A fading margin of 3dB is used.

5 Performance Results

The *Grade of Service* (GoS) [5], which is well known in connection oriented communication system, is used to determine the maximum load which can be carried. A small value of the GoS means a good grade of service for the System. A GoS of less than 1% seems to be acceptable for a mobile communication system.

$$GoS = \frac{\text{blocked setup trails} + 10 \cdot \text{lost calls}}{\text{total number of calls}} \tag{2}$$

A simple approach for a Call Admission Control is used to determine if a connection can be accepted or not. When a connection request occurs (transition from the passive to the active state) the AP calculates the capacity which is available if all active terminals would transmit with maximum transmission power. If the mean rate of all connections plus an overbooking of 10% is available, the connection is accepted otherwise it is rejected.

In Fig. 5 the influence of PC on the GoS is shown. If no PC is used the average load per AP which can be carried by the system is around 4.4 Mbit/s. Using PC only in uplink direction leads to an improvement of around 14%. In case that also in downlink direction the transmission power can be adjusted separately for each terminal – which is not foreseen in the standard so far – the load can be increased to around 5.5 Mbit/s (+28%).

In Fig. 6 the influence of the load on the transmission power is shown. First of all, it is visible that with increasing load the transmission power increases since higher PHY-Modes are selected to provided the required data rate. Furthermore, the transmission power increases with increasing distance between AP and MT. The algorithm to control the transmission power introduced in section 3 tries to select the same power for all terminals. But regarding to Fig. 6 it can be seen that this target is not reached. The explanation can be found in the distribution of the PHY-Modes. In the left part of Fig. 7 the selected PHY-Mode without PC is shown. At the border of the cell the interference condition allows only low PHY-Modes to be used. Thus the transmission power can not be reduced that much. Closer to the AP higher PHY-Modes are used offering a larger range of power adjustments.

Finally, the fraction of the MAC Frame which is used for transmission is discussed (cf. Fig. 8). As already stated, PC reduces the *unused* part of the MAC Frame.

It was shown that PC in combination with LA leads to a dynamic exchange of capacity between APs in case of variating traffic. Is there a similar

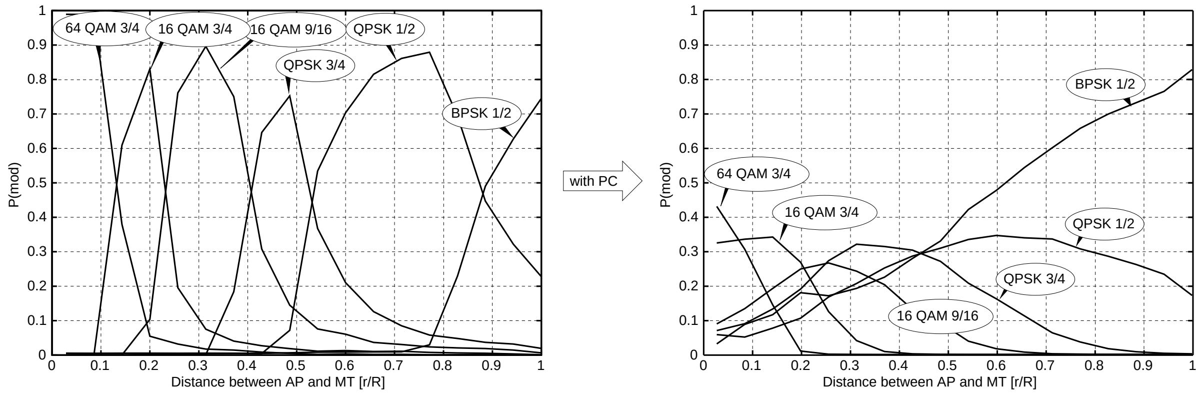

Figure 7: PHY-Mode Distribution

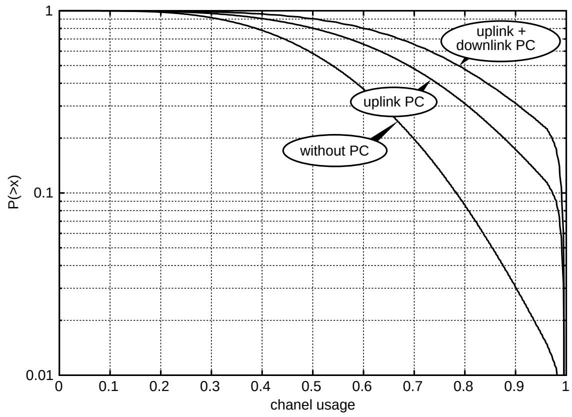

Figure 8: Usage of the MAC-Frame ($5\,{}^{\mathrm{Mbit}}/_{\mathrm{s}}$)

gain concerning the maximum throughput? Maximum throughput in this context means that all APs try to transmit as much as possible. The following data rates were achieved:

without PC:	$8.71\,{}^{\mathrm{Mbit}}/_{\mathrm{s}}$
with PC:	$8.87\,{}^{\mathrm{Mbit}}/_{\mathrm{s}}$

With the introduced algorithm, PC only results in a slight increase of the maximum throughput. All APs use the highest suitable PHY-Mode to maximise the data rate and therefore only MTs located closed to the AP are able to reduce their transmission power. The transmission power in dependence of the distance between AP and MT is also shown in Fig. 6.

6 Conclusion

In this paper an easy to realise but efficient strategy for power control in combination with LA for H/2 networks was presented. The approach is based on the idea to reduce the transmission power as long as the MAC-Frame is not completely used and to reduce the resulting interference in neighbour cells. This strategy results in a dynamic capacity exchange between APs. Further developments will consider the delay requirements when increasing the transmission power. It was shown that the system capacity can be increased significantly in case of time variant load situations.

References

[1] ETSI BRAN, *HIPERLAN Type 2 Technical Specification TS 101 761-1 V1.1.1, Data Link Control (DLC) Layer, Part 1 - Basic Data Transport Function*, April 2000. 2, 3

[2] ETSI BRAN, *HIPERLAN Type 2 Technical Specification TS 101 761-2 V1.1.1, Data Link Control (DLC) Layer, Part 2 - Radio Link Control (RLC) sublayer*, April 2000. 3

[3] Z. Lin, G. Mamgren, and J. Torsner, "System Performance Analysis of Link Adaptation in HiperLAN Type 2," in *IEEE 50^{th} Vehicular Technology Conference (VTC) 2000 (Fall)*, (Boston (MA), USA), pp. 1719–1725, September 2000. 3

[4] J. Rapp, "Hiperlan/2 System Throughput and QoS with Interference Improving Strategies," in *IEEE VTS 53rd, Vehicular Technology Conference, Spring*, (Rhodes, Greece), p. Paper 243, May 2001. 3.1

[5] ETSI, *Radio Equipment and Systems (RES): Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part3: Medium Access Control (MAC) layer*, 1996. ETS 300 175-3. 5

7 Biography

Andreas Krämling (akr@comnets.rwth-aachen.de) received his Diploma degree in electrical engineering in 1996 from Aachen university of Technology, Germany. In 1996 he joined the Department of Communication Networks, Aachen University of Technology, as a Research Assistant. Currently he is working towards his Ph.D. thesis which is focused on dynamic channel assignment. His research interests are in the field of mobile communication protocols, especially for HIPERLAN/2 systems, and radio resource management.