RADIO NETWORK SOLUTIONS FOR HIPERLAN/2

Johan Torsner and Göran Malmgren

Ericsson Radio Systems AB, S-16480 Stockholm, Sweden

Abstract - HIPERLAN/2 is a wireless LAN system currently being specified by ETSI BRAN for use in the 5 GHz band. The system uses a channel spacing of 20 MHz and will provide data rates up to 54 Mb/s (2.7 bit/s/Hz). The typical application is communication between portable computers and a fixed data network. The high data rates together with the limited number of available frequency carriers (approximately nine) implies that deploying a full coverage, multi cell system is challenging. A potential radio network solution based on automatic frequency assignment, link adaptation and multi beam antennas is presented in this paper. Simulation results show that the presented solution provide a high peak data rate and system throughput.

I. INTRODUCTION

ETSI BRAN (European Telecommunications Standards Institute Broadband Radio Access Networks) develops standards and specifications for broadband radio access networks that cover a wide range of applications intended for different frequency bands. A system currently being specified by BRAN is HIPERLAN type 2 (H/2) which will provide high speed (up to 54 Mb/s data rate) communications between portable computing devices attached to an IP, ATM or UMTS backbone network. H/2 will be capable of supporting multimedia applications and the typical operation environment is indoor with restricted user mobility. In Europe, the frequency band 5.15-5.25 GHz currently allocated to H/1, will most likely be available also for H/2 systems. Additional spectrum above 5.25 GHz may also be available for H/2 systems, which than will share the spectrum with earth exploring satellites and/or radar equipment. H/2 can also be deployed in the U-NII band in the US. We here assume that 200 MHz uninterfered bandwidth can be used for a H/2 system in both Europe and USA. Ongoing discussions may also result in H/2 being deployed in a similar frequency band in Japan.

In order to support the required peak data rate of 25 Mb/s, a channel spacing/bandwidth of 20 MHz has been adopted in ETSI BRAN. With 200 MHz bandwidth, typically nine frequency carriers are available if a guard band of one channel is applied. Since H/2 will be used in an unlicensed band, it may occur that an operator can not utilize the entire frequency band due to interference from other operators in the close vicinity. Furthermore, a high radio quality is required to fulfil the peak data rate requirement of 25 Mb/s.

The H/2 system is likely to be deployed in a wide range of environments, such as office buildings, exhibition halls, airports, industrial buildings and outdoor deployment. Altogether, this implies that deploying a full coverage, multi-cell system is challenging. It is clear that the system must be able to adapt to different propagation and interference environments.

In this paper it is shown that a radio network solution based on automatic frequency planning together with link adaptation achieves a high peak data rate and system throughput. Further extensions using multi beam antennas seem appropriate in line of sight (LOS) environments. With the proposed solution it is possible to deploy full coverage, multi cell systems in both non line of sight (NLOS) and LOS environments.

II. REQUIREMENTS ON HIPERLAN/2

The most important requirements on the H/2 system [1] are summarized here:

- Radio Range: H/2 shall provide a range of 30 m in a typical indoor environment and up to 150 m in a typical outdoor or large open indoor (e.g. large factory hall, airport) environment.
- Peak Data Rate: H/2 shall provide a peak input data rate of at least 25 Mb/s to the PHY layer.
- Capacity and Coverage: In a single operated multi-cell environment the average system throughput (per AP) should at least be 20 Mb/s (input to the PHY layer). In 95% of the area the mobile terminal (MT) should be able to provide at least 4 Mb/s as input to the PHY layer.

Further, it is desired that no manual planning of the radio network shall be needed, i.e. frequency planning and adjustment of radio parameters should be performed automatically by the system.

III. SYSTEM DESCRIPTION

A typical H/2 system consists of a number of access points (APs) connected to a backbone network, e.g. an ethernet LAN. An AP can use an omni antenna, a multi beam antenna, or a number of distributed antenna elements. The system supports mobility between access points on the same backbone network, i.e. handover is made between APs.

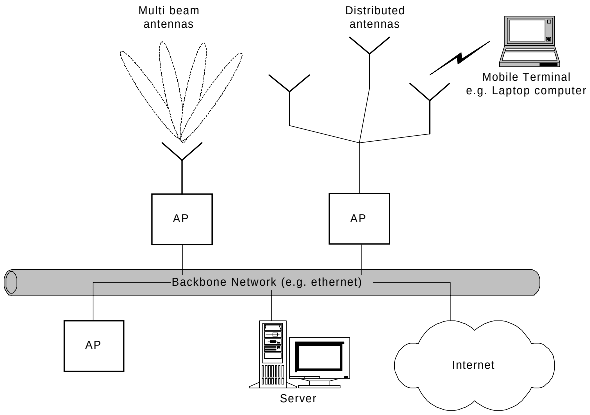


Figure 1. System Overview HIPERLAN type 2 (H/2)

Physical layer

Currently a strong alignment has been achieved between three standardisation bodies, IEEE 802.11a (U.S), ETSI BRAN (Europe) and MMAC (Japan) on the PHY layer. All have adopted OFDM with 64 subcarriers, where 48 subcarriers are modulated for data transmission and 4 subcarriers are used for pilot signals. The remaining 12 subcarriers are set to zero. In order to support link adaptation a number of PHY modes have been defined, where a PHY mode corresponds to a signal constellation and code rate combination. These are shown in Table 1. The demodulation is coherent. Details about the proposed physical layer can be found in [2].

Data Link Control (DLC)

A centralised controlled Data Link Control (DLC) layer is adopted in H/2, which means that the access point controls how the resources are allocated in a MAC frame. Each MT requests capacity in future MAC frames when it has some data to send. This request is sent either in a Short transport CHannel (SCH), which is piggy backed to the uplink data transmission, or in the random access slots. The general frame shown in Figure 2 can be utilised for different radio network solutions. In the switched multi beam or distributed antenna configuration the Broadcast Control cHannel (BCH) is transmitted sequentially on each antenna element. Immediately after the BCH an announcement is made on all active antenna elements (i.e., those who will carry data in the upcoming MAC frame) conveying the structure of the MAC frame. This is done through the Frame Control cHannel (FCH) which grants resources for different connections. Note that one MT could have multiple connections, where each connection carries a certain type of traffic. This enables the DLC to act accordingly to the required QoS.

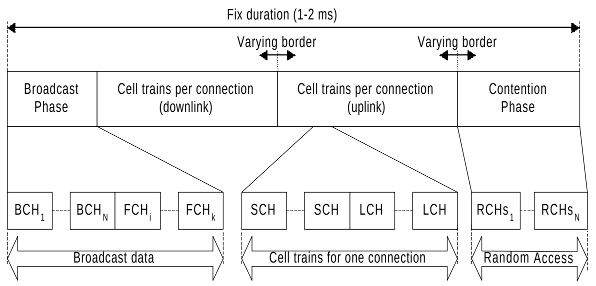


Figure 2. MAC frame for HIPERLAN type 2

The resource grants (RGs) in the FCH allocates a part of the frame for a certain connection. An absolute pointer is used together with a specification on the number of Short transport CHannels (SCH, for resource request and ARQ ACK/NACK messages) and Long transport CHannels (LCH, for user data). Furthermore, the PHY mode is also specified per connection. The MAC frame length is fix, but the length is not yet decided. Most likely, the frame length will be 1-2 ms.

IV. RADIO NETWORK

Dynamic Frequency Selection (DFS)

As no manual planning of the system shall be needed, the system must automatically allocate frequencies to each AP for communication. It is assumed that the dynamic frequency selection (DFS) reacts on slow changes in the radio environment, e.g. when a new AP is installed. The DFS does normally not react to movement of users or short term changes in the traffic distribution. The frequency selection is based on filtered interference measurements performed by the AP and its associated MTs. The communication will be halted when the AP performs interference measurements and no traffic will be scheduled to MTs that are ordered to measure. The DFS allows several operators to share the available frequency spectrum.

Link Adaptation (LA)

The radio quality, in terms of C/I is highly dependent on the radio environment. The C/I level also changes over time, depending on the traffic in surrounding cells. In order to maximize the link throughput, a link adaptation scheme is used, where the PHY mode can be adapted to the time varying link quality. Link adaptation has been studied in e.g. [3]. Due to the rapid time variations of the link quality, it is deemed difficult to assign PHY mode based on the momentary link quality. Instead, the PHY mode is assumed to be adapted at a time interval significantly larger than the MAC frame duration (e.g. 5-10 MAC frames).

The link quality is estimated from measurements, e.g. C/I estimates from the training sequence in each MAC frame. Link adaptation is used in both uplink and downlink, where the AP measures the link quality on the uplink and signals to the MT which PHY mode to use for uplink communication. In a similar way, the MT measures the link quality on the downlink and signals a PHY mode suggestion to the AP for downlink communication. However, the AP is responsible for the final PHY mode selection for both uplink and downlink.

Mode	Data Rate	Mod.	Code Rate
M1	6 Mb/s	BPSK	1/2
M2	9 Mb/s	BPSK	3/4
M3	12 Mb/s	QPSK	1/2
M4	18 Mb/s	QPSK	3/4
M5	27 Mb/s	16 QAM	9/16
M6	36 Mb/s	16 QAM	3/4
M7	54 Mb/s	64 QAM	3/4

Table 1 Data rate (input to PHY layer), modulation and code rate for the modes M1-M7. Mode M7 is optional.

Link simulations have provided throughput as a function of C/I for the defined PHY modes on a channel with 50 ns delay spread, see Figure 3. The results are only valid for ideal selective repeat ARQ. If no link adaptation is used in the system, i.e. a single PHY mode is used, the parameters for this mode should be selected to fulfil the requirements on range and data rate mentioned in Section II. However, no single PHY mode will fulfil both requirements. In the performance analysis, PHY mode M4 (18 Mb/s) is used as reference, as this is the mode with highest data rate among the modes that fulfils the requirement of 30 m range in a typical office environment. It is assumed that the range requirement is fulfilled if the channel packet error rate is below 10% in a noise limited environment.

Multi beam antennas

Multi beam antennas have been discussed in ETSI as a means to improve the link budget and increase the C/I ratio in the radio network. The MAC protocol and the frame structure in H/2 allow multi beam antennas with up to 7 beams to be used. The beam selection is MT initiated, i.e. each MT requests which beam that should be used for downlink communication, based on measurements on the broadcast fields that are transmitted sequentially in each beam. The AP can, if desired, select another beam for the uplink communication.

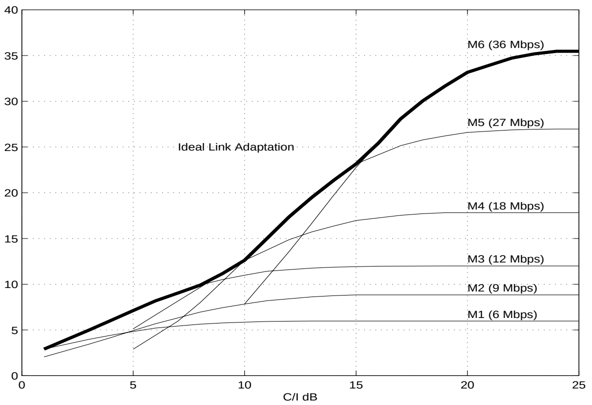


Figure 3. Throughput as a function of C/I for the six mandatory PHY modes. The thick line indicates the throughput for ideal link adaptation.

V. PERFORMANCE ANALYSIS

Modelling of the radio network

In this paper, an algorithm for distributed frequency assignment proposed in [4] has been used to develop a frequency plan prior to the simulations. The frequency plan is fix during the simulations.

The link adaptation is modelled by updating the PHY mode every 10th MAC frame. The position of the receiver is fixed during the update interval, and the interferers are placed randomly each MAC frame. In each update interval the throughput for all PHY modes is estimated, and the mode achieving the highest throughput is used during the next update interval.

The beam selection for multi beam antennas is modelled by using the beam with the highest received downlink signal strength, i.e. lowest pathloss. As the interference, arising from other cells, is independent of the beam selection, this approach will also maximise the received downlink C/I ratio. The same beam is used for both uplink and downlink communication. In the simulations the system performance for a system with omni antennas is compared to the performance for a system using multi beam antennas with 6 beams. The multi beam antenna has 90 degrees 3 dB lobewidth and 6 dBi antenna gain.

Simulation Environment

For radio network evaluations, two "typical" environments have been considered, an office building and an open exhibition hall. The office building is dominated by NLOS propagation, and the exhibition hall consists only of LOS propagation.

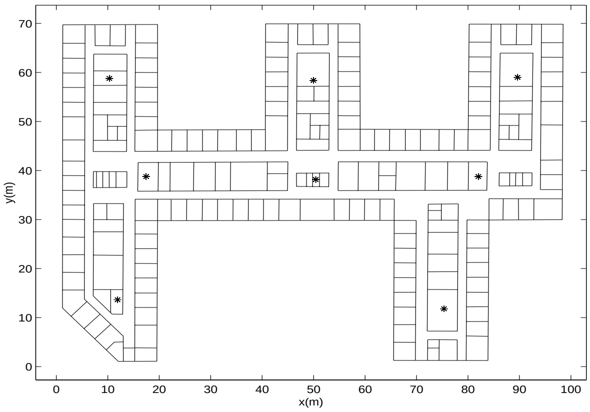


Figure 4. One floor in the simulated office building and the positions of the APs (*).

The office scenario included a building with five floors and a large number of MTs. Each floor was covered by eight APs which were located at the same position on every floor, see Figure 4. The average path loss (i.e. without fast fading) between a MT and a AP was calculated using the extended Keenan-Motley model [5] which includes the attenuation by the distance, walls and floors in the direct propagation path (the straight distance between the MT and AP). The model is based on 900 MHz propagation measurements. The frequency dependent term in the model as well as the wall and floor attenuation is however modified for 5 GHz.

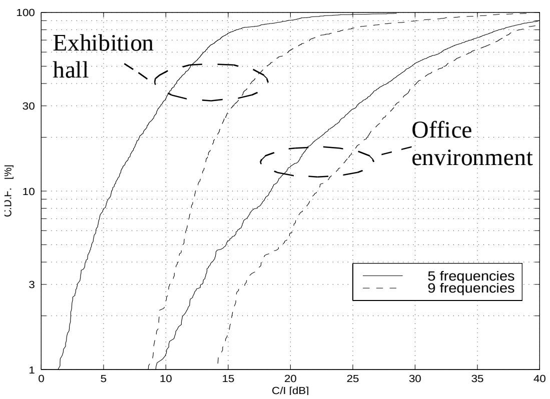
The exhibition hall scenario consisted of a large building with one floor and no inner walls. The hall was covered with 16 access points placed in a rectangular grid with a site to site distance of 60 m. It was assumed that very high capacity is needed in this environment. Therefore, the large number of installed access points. In this scenario, a LOS propagation model was used. Furthermore, lognormal fading with a standard deviation of 2 dB was added in order to model shadowing caused by e.g. people moving around in the environmentThe mobiles were randomly placed in the buildings according to a uniform distribution. The simulation technique was static: each iteration corresponded to a traffic situation unrelated to the previous one, i.e. "snapshots" were taken of the situation in the building. The system was analysed at a full load situation, i.e. all access points and terminals were active. Only results from the downlink is presented in this paper, as the downlink is assumed to carry the majority of the data traffic. The downlink interference arises from other APs as well as from other MTs, due to the unsynchronised TDD MAC frame. External interference was modelled by assuming that a second operator is present, using four of the nine carriers. The important simulation parameters are summarized in table 2.

Simulation Parameter	Value
Number of frequencies	9 / 5
System load	100 %
Downlink traffic	75 %
Adjacent channel suppression	30 dB
Handover hysteresis	5 dB
AP/ MT power (EIRP)	20 dBm
Noise power	-95 dBm
Antennas (omni)	0 dBi
Antennas (multi beam)	6 dBi, 90 deg.
Wall attenuation (office building)	3 dB
Floor attenuation (office building)	20 dB

Table 2. Important simulation parameters

VI. SIMULATION RESULTS

Figure 6 shows the downlink C/I for a system with omni antennas. The C/I is shown for 9 and 5 frequency reuse, corresponding to a single operator and a two operator scenario respectively. These distributions are the basis for the system throughput performance evaluation below.



Downlink C/I with 9 and 5 frequency reuse for a system with omni antennas.

Note that the C/I varies greatly between the exhibition hall and the office environmentThe impact on C/I with multi beam antennas is shown in Figure 7. The 10 percentile of C/I is improved 2-3 dB in the exhibition hall. However, the mean C/I is improved more than 5 dB, which gives an significant improvement of throughput.

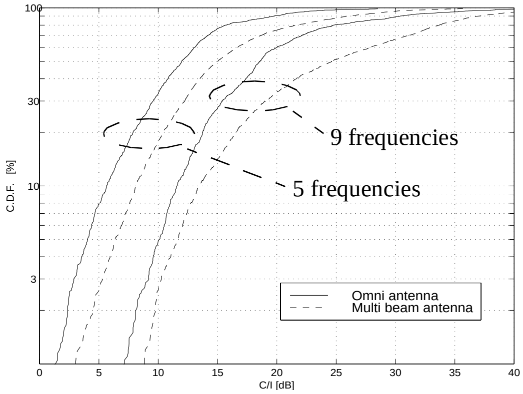


Figure 5. Downlink C/I with 9 and 5 frequency reuse in the exhibition hall for a system with omni antennas and multi beam antennas (6 beams) respectively.

By combining the previous shown link simulation results (Figure 3) with the C/I distributions (Figure 6 and 7), the system throughput can be derived. The link quality (C/I) of each user is mapped on a corresponding throughput. The system throughput is then calculated as the mean throughput for all users, which corresponds to a scheduling strategy where each user is allocated the same amount of radio resources, in terms of transmitted OFDM symbols.

	9 frequencies	5 frequencies
Exhibition hall	16.8 Mb/s	12.9 Mb/s
Office	17.8 Mb/s	17.5 Mb/s

Table 3: System throughput for PHY mode M4 (18 Mb/s) in a system with omni antennas

Note that the system throughput calculation does not consider the bursty nature of packet data traffic. It can be seen as the achievable data rate during e.g., a large file transfer. The system throughput for the fixed PHY mode M4 in a system with omni antennas is shown in Table 3. The throughput in the office environment is very close to the maximum value 18 Mb/s which is natural since the C/I level in the office environment is very high, both for 9 and 5 frequency reuse. In the exhibition hall, the interference from other APs degrade the performance slightly. When link adaptation is used (Table 4) the system throughput is increased significantly. The system throughput is well above the requirement of 20 Mb/s in all cases except when two operators share the spectrum in the exhibition hall.

	9 frequencies	5 frequencies
Exhibition hall	27.7 Mb/s	16.7 Mb/s
Office	34.6 Mb/s	33.7 Mb/s

Table 4: System throughput with link adaptation in a system with omni antennas

Finally, the system throughput when multi beam antennas are used in the exhibition hall is shown in Table 5. The system throughput is increased, but the requirement is still not fulfiled in the two operator case

	9 frequencies	5 frequencies
Exhibition hall	29.4 Mb/s	18.9 Mb/s

Table 5: System throughput with link adaptation in a system with multi beam antennas.

VII. CONCLUSION

The C/I level differs significantly between different environments. In the office environment, which is dominated by NLOS propagation, the system throughput is relatively high even without link adaptation or multi beam antennas. In the exhibition hall, which consists of LOS propagation, the system throughput is lower. However, if link adaptation and multi beam antennas are used, the system throughput requirement of 20 Mb/s can almost be fulfilled even when two operators share the available spectrum. Note that the DLC overhead is larger when multi beam antennas are used. The overhead also depends on the MAC frame length. Therefore, the results for multi beam antennas may differ slightly from the values presented here, as no DLC overhead is included in the simulations.

VIII. REFERENCES

[1] ETSI BRAN, "Requirements and Architectures for Wireless Broadband Access", DTR/BRAN-010002 V0.1.3

[2] Uwe Dettmar et al., "Modulation for HIPERLAN Type 2", to appear in Proc. IEEE 49th VTC'99

[3] A. Furuskär et al., "System Performance of EDGE; a Proposal for enhanced Data Rate in Existing Digital Cellular Systems", in Proc. IEEE VTC'98

[4] M. Almgren et al., "Slow Adaptive Channel Allocation for Automatic Frequency Planning", in ICUPC 96

[5] C.Törnevik et al., "Propagation Models, Cell Planning and Channel Allocation for Indoor Applications of Cellular Systems", in Proc.IEEE 43rd VTC'93.