Throughput Analysis of ETSI BRAN HIPERLAN/2 MAC Protocol Taking Guard Timing Spaces into Consideration

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Abstract

In this paper we examine the effects of the required portions of guard timing spaces in a MAC frame of ETSI BRAN HIPERLAN/2 system such as inter-mobile guard timing space in UL(Up Link) duration, inter-RCH(Random CHannel) guard timing space, sector switch guard timing space. In particular, we calculate the number of OFDM(Orthogonal Frequency Division Multiplexing) symbols required for these guard timing spaces in a MAC frame. We then evaluate the throughput of HIPERLAN/2 system as we vary parameter such as the guard time values defined in [2], the number of DLCCs(Data Link Control Connections), and the number of RCHs. Finally we show by numerical results that the portions for the total summation of required guard timing spaces in a MAC frame are not negligible, and that they should be properly considered when trying to evaluate the performance of MAC protocol of HIPERLAN/2 system and also when determining the number of RCHs as well as the number of DLCCs in UL PDU trains at an AP/CC(Access Point/Central Controller).

I. INTRODUCTION

HIPERLAN/2, providing high-speed communications between mobile terminal and various broadband infrastructure networks and representing a centralized access of MAC protocol, is an ETSI BRAN standard with a 2ms duration of MAC frame. There have been studies which analyze throughput of HIPERLAN/2 MAC layer[4][5]. However, they omit to subtract from the total length of a MAC frame some of non-negligible components of overheads in a MAC. Firstly, they do not take into account some guard timing spaces in order to cope with propagation delay. Secondly, they omit to subtract the overhead portions of DL(Down Link) PDU train as well as SCHs(Shot transmit CHannels) of UL PDU train from a MAC frame duration. Because of these reasons, the previous works tend to overestimate the possible length of LCHs as the pure user data path, and consequently may lead to inflating result of its throughput. Having considered the missing points of the previous works, what we try to show in this paper is the effects on the throughput of the required guard timing spaces imposed on a MAC frame based on [1][2]. Specifically we observe the results as varying the number of active user's DLCC as well as guard time values defined in [2]. Finally we show by numerical results that the whole required portions of the guard timing spaces are not negligible within a MAC frame duration of 500 OFDM symbols, as the number DLCC and RCH is increased. These overheads should be properly considered when evaluating the performance of HIPERLAN/2 system, and also when determining the number of RCHs as well as the number of DLCCs in UL PDU trains at an AP/CC.

In section II we introduce system parameters to evaluate throughput of HIPERLAN/2 system in this paper. In section III we analyze the length of each PDU parts regarding guard timing spaces for throughput analysis in a MAC frame. Section IV deals with various numerical results examining the effects of the number of DLCCs as well as guard time values. Finally we end with conclusions in section V.

II. SYSTEM PARAMERTERS

The PHY(physical) layer of HIPERLAN/2 is based on the modulation scheme OFDM with 52 sub-carriers whose possible modulations are BPSK(Binary Phase Shift Keying), QPSK(Quaternary Phase Shift Keying), and 16QAM(Quadrature Amplitude Modulation) for mandatory, and 64QAM for optional. In order to improve radio link capacity due to different interference situations and distances of MTs to the AP or CC, a multi-rate PHY layer is applied, where the appropriate mode can be selected by the link adaptation scheme. We assume that the preambles for UL PDU trains and RCH PDUs are long preamble i.e. four OFDM symbols and each active user has two DLCCs; one is for UL and the other is for DL. We further assume that every DLCC has one SCH, which is only used to convey control user data, and also that the guard time value for RCH specified in BCCH(Broadcast Control CHannel) is concurrently applied to that for UL inter-PDU trains. We define and assume system parameters for numerical calculation as TABLE II.

TABLE II
PARAMERTERS FOR NUMERICAL CALCULATIONS

Parameters	Meaning	Value
L_X	The length of X PDU in a MAC frame.	Variable
BpS_X	The number of bytes coded per OFDM symbols for X PDU train.	Depend on PHY layer modes
N_{sec}	The number of sectors per AP.	1 ~ 8
N_{IE}	The number of IE blocks in whole sectors.	Variable
NX_{SCH}	The total number of SCHs in X PDU train.	1
NX_{MT}	The number of active MTs in X PDU train.	Variable
$NDiL_{MT\_Diff}$	The number of different index of transmitter between two consecutive MTs in DiL PDU train.	Variable (Optional)
S_g	Sector switch guard time	800ns
P_g	Propagation delay guard time	2.0μs ~ 12μs
UD_{OFDM}	Unit Duration of an OFDM symbol	4μs
Δ(t)	Delta step function	0, t≤1 and t, elsewhere

III. THROUGHPUT ANALYSYS

A. BCH PDU Trains Length

The BCH(Broadcast CHannel) has the size of 15 octets long and shall be transmitted using BPSK with coding rate 1/2. The size of preamble shall consist of four OFDM symbols(16μs). According to Fig.1 we can calculate the length of BCH PDU train as (1) where sector switch guard timing space should be imposed on every interval between two BCHs if multi-sector is used.

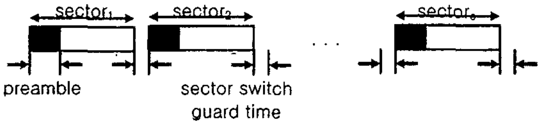

Fig.1 The structure of BCH PDU trains

$$L_{BCH} = 9*N_{sec} + \frac{\Delta(N_{sec})\cdot S_g}{UD_{OFDM}}. \quad (1)$$

B. FCH+ACH PDU Trains Length

A FCH(Frame CHannel) shall be built of fixed size IE(Information Element) blocks. Every IE block shall contain three IEs, each with a length of eight octets and a CRC(Cycle Redundancy Check) of length 24 bits which shall be calculated over the three consecutive IEs. Thus a FCH shall consist of multiple of 27 octets.

$L_{FCH+ACH}$ =

$$2*\Delta(N_{sec}) + 9*\left\lceil \frac{N_{IE}\cdot 8}{24} \right\rceil + 3*N_{sec} + \frac{(N_{sec}-1)\cdot S_g + P_g}{UD_{OFDM}}. \quad (2)$$

Equation (2) shows the length of the FCH+ACH PDU train in a MAC frame. In the same fashion as in BCH PDU train, the sector switch guard timing space is set on every interval between FCH+ACH PDUs, and the propagation delay guard timing space is also added at the end of the FCH+ACH PDU train. If omni-sector is used only one preamble, size of four OFDM symbols, shall be imposed on the BCH+FCH+ACH train without any additional ticks.

C. DL PDU Trains Length

The preamble, two OFDM symbols, is preceded with every first PDU, distinguished by DLCC-ID, in same MAC-ID, i.e. each MAC-ID GROUP, which consists of different DLCC-ID PDUs has only one preamble. Equation (3) shows the length of the DL PDU train except for LCHs in this PDU train.

$$L_{DL\text{-}LCH} = 2*NDL_{MT} + \left\lceil \frac{9}{BpS_{SCH}} \right\rceil *NDL_{SCH} + \frac{P_g}{UD_{OFDM}}. \quad (3)$$

D. DiL PDU Trains Length as Optional

A guard timing space is needed where different TX mobile-id is positioned between two consecutive PDU trains. Equation (4) shows the length of DiL PDU train except for LCHs in this PDU train.

$L_{DiL\text{-}LCH}$ =

$$4*NDiL_{MT} + \left\lceil \frac{9}{BpS_{SCH}} \right\rceil *NDiL_{SCH} + \frac{(NDiL_{MT\text{-}Diff}+1)\cdot P_g}{UD_{OFDM}}. \quad (4)$$

E. UL PDU Trains Length

Being different from DL PDU trains, UL PDU train always needs a guard timing space between two PDU trains whose MAC-IDs are different each other. Equation (5) depicts the length of the UL PDU train except for LCHs duration. The guard timing spaces are directly proportional to the number of DLCCs used by active users in UL PDU trains as (5) shows.

$L_{UL\text{-}LCH}$ =

$$4*NUL_{MT} + \left\lceil \frac{9}{BpS_{SCH}} \right\rceil *NUL_{SCH} + \frac{\Delta(NUL_{MT})\cdot P_g}{UD_{OFDM}} \quad (5)$$

F. RCH PDUs Length

Between RCHs shall be space for preamble and guard timing space as in Fig.2. Equation (6) gives the total length of RCHs.

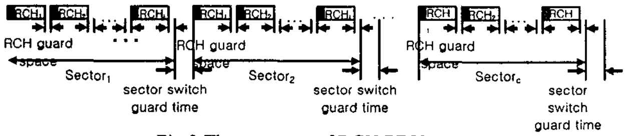

Fig.2 The structure of RCH PDUs

$$L_{RCH} = 7*N_{RCH} + \frac{N_{RCH}\cdot P_g + \Delta(N_{sec})\cdot S_g}{UD_{OFDM}} \quad (6)$$

G. Total Required Guard Timing Spaces and Maximum Throughput in a MAC Frame

Using equations from (1) to (6), we can specify their durations into two parts where the first is the total length for the preambles and the signaling overheads($L_{PRE+SOH}$), and the second is the total length for the guard timing spaces(L_{GTS}). Subtracting $L_{PRE+SOH}$ and L_{GTS} from the total length of a MAC frame(L_{MF}) in a number of OFDM symbols, we can now calculate the total length of LCHs for DL, DiL, and UL PDU trains in a MAC frame as (9).

$L_{PRE+SOH}$ =

$$12*N_{sec} + 2*\Delta(N_{sec}) + 9*\left\lceil \frac{N_{IE}\cdot 8}{24} \right\rceil + 2*(NDL_{MT} + 2*NDiL_{MT} + 2*NUL_{MT}) + \left\lceil \frac{9}{BpS_{SCH}} \right\rceil *(NDL_{SCH} + NDiL_{SCH} + NUL_{SCH}) + 7*N_{RCH}. \quad (7)$$

L_{GTS} =

$$\left\lceil \frac{\{2\cdot\Delta(N_{sec})+N_{sec}-1\}\cdot S_g + \{3+NDiL_{MT\_Diff}+\Delta(NUL_{MT})+N_{RCH}\}\cdot P_g}{UD_{OFDM}} \right\rceil . \quad (8)$$

$$L_{LCH} = L_{MF} - (L_{PRE+SOH} + L_{GTS}). \quad (9)$$

Here one of our main concerns is L_{GTS} imposed on MAC frame duration and its effects will be discussed in section IV. In order to get maximum throughput we use (10) as given in [4] as follows :

$$TP_{max} = \left\lfloor \frac{L_{LCH}\cdot BpS_{LCH}}{54} \right\rfloor \cdot \frac{x}{\left\lceil \frac{x+4}{48} \right\rceil} \cdot \frac{8}{t_{frame}} \quad (10)$$

where x is the length of the user data packets in bytes.

IV. NUMERICAL RESULTS

In this section we describe the numerical results of total required guard timing spaces effects on the maximum throughput by the number of RCHs, the number of DLCCs, and guard time values under various modulation schemes of HIPERLAN/2 system. Referring to (8) we can see the effect of guard timing spaces required to support RCHs and NUL_{MT} in Fig.3. When the sum of number becomes 70, then the required number of OFDM symbols to carry their total guard timing spaces is 37 for minimum guard time value(2μs), and 219 for maximum guard time value(12μs).

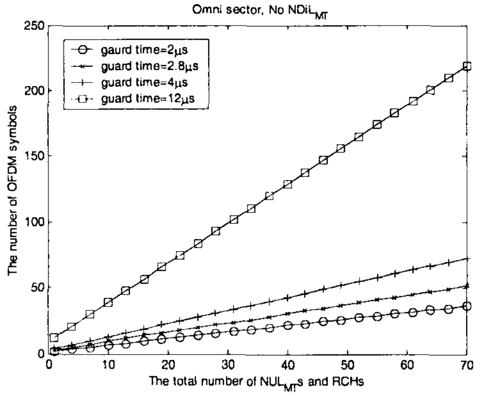

Fig.3 The number of OFDM symbols by L_{GTS} for $NUL_{MT}s$ and RCHs

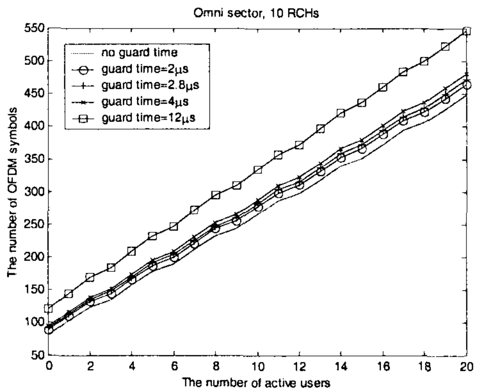

Fig.4 The number of OFDM symbols by $L_{PRE+SCH}$ and L_{GTS}

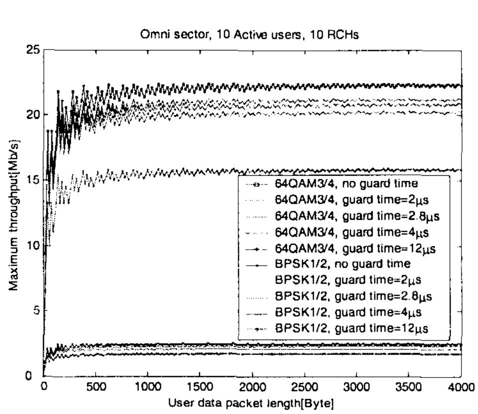

Fig.5 Throughput by modulations and guard time values

Increasing the number of active users in the system we have plotted the total required number of OFDM symbols according to (7), (8) in Fig.4. We can realize the differences of how many additional number of OFDM symbols there are needed when various guard time values defined in [2] are adapted. Under the assumptions and parameters we have made in Section II, when the number of active users reaches 20 the required number of OFDM symbols is over the total size of a MAC frame for the case that maximum guard time value is used. The differences between the case of no guard time value and the cases of various guard time values are mainly influenced not by the assumptions but by guard time values, and its maximum difference is almost 100 OFDM symbols that is 20% of resources in a MAC frame. In Fig.3 and Fig.4 we can see the differences that are becoming bigger by increasing the number of active users. This is owing to the fact that the total required guard timing spaces are directly proportional to the number of UL DLCCs used by active users as well as the allowed number of RCHs in the system. Fig.5 compares the maximum throughputs over the length of user data packet by the maximum modulation schemes(64QAM with coding rate 3/4), the minimum modulation scheme(BPSK with coding rate 1/2) and various guard time values. We can see that the system throughputs are seriously degraded in comparison to the case with no guard time value in both maximum and minimum modulations as the guard time value has increased. The graphs of BPSK with coding rate 1/2 for 2μs guard time value and BPSK with coding rate 1/2 for 2.8μs guard time value are completely overlapped with the third curve from the last one due to the property of floor function in (10).

V. CONCLUSIONS

In this paper we have discussed the effects of guard timing spaces in a MAC frame of ETSI BRAN HIPERLAN/2 system on the throughput performance. These guard timing spaces are needed between RCHs and different MAC-ID PDU trains in UL, and different sectors. We estimated throughputs under various guard time values defined in [2], the number of RCHs and number of DLCCs used by active users. We analyzed the required guard timing spaces in every PDU trains according to [1][2] and calculated their lengths in a number of OFDM symbol imposed on MAC frame depending on the number of RCHs and the number of DLCCs. The numerical results showed that the throughputs of system are dramatically dropped as the guard time value becomes bigger. Also we showed by numerical results that it should be carefully estimated by AP/CC to determine the number of RCHs and the number of DLCCs of UL PDU trains because they are directly proportional to the length of required guard timing spaces and may, otherwise, degrade the performance of the system.

VI. REFERENCES

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