Random Channel Allocation Scheme
in HIPERLAN/2

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Abstract. HIPERLAN/2 is one of the standards for high-speed wireless
LANs developed by ETSI BRAN. A mobile terminal (MT), when it has
messages to send in the uplink channel, may use contention slots, called
random access channels (RCHs), to send the resource request messages.
Based on successful resource request messages from the MTs, the access
point (AP) allocates uplink channel resources dynamically. The number
of RCHs in one MAC frame should be adjusted in such way that the
access delay for request messages is kept small without underutilizing
the RCHs. In this paper, we propose a new RCH allocation scheme using
the splitting algorithm, which dynamically adjusts the number of RCHs
according to the current traffic situation. The simulation results show
that our scheme performs well in terms of channel throughput, access
delay and delay jitter compared with previously proposed RCH allocation
schemes.

1 Introduction

As wireless LAN standards, ETSI BRAN’s HIPERLAN/2 and IEEE’s 802.11a
are currently suggested for providing raw data rates of up to 54 Mbps in the
5 GHz band. The main differences between them occur at the MAC layer[2,4-
8]. While IEEE 802.11a uses a distributed MAC protocol that is based on a
CSMA/CA, HIPERLAN/2 is based on a TDMA/TDD approach using a MAC
frame with a period of 2\text{ms}[1].

In HIPERLAN/2, the MT, when it has messages to send in the uplink channel,
may use contention slots, which are called RCHs, to send the resource request
message using the slotted ALOHA scheme. Based on successful resource request
messages from the MTs, the AP allocates uplink channel resources dynamically
considering message types. The number of RCHs in one MAC frame should be
adjusted in such way that the access delay for request messages is kept small
without underutilizing the RCHs. It is desirable that the number of RCHs is
dynamically adapted by the AP depending on the current traffic state. For ex-
ample, the allocation of excessive RCHs may waste radio resources, and on the
other hand, the allocation of insufficient RCHs may result in many collisions in
access attempts.

In this paper, we propose a new adaptive random channel allocation scheme
based on the splitting algorithm. The simulation results show that the proposed
scheme achieves higher throughput, and incurs lower access delay and delay jitter
than the previously proposed RCH allocation schemes.

This paper is organized as follows. In section 2, we describe HIPERLAN/2’s
MAC protocol and related research. A new random channel allocation scheme
is proposed in section 3. Using the simulation, we show the performance of the
proposed scheme in section 4. We conclude this paper in section 5.

2 Related Research

2.1 Basic MAC frame structure for HIPERLAN/2

One MAC frame of HIPERLAN/2 has fixed duration of 2ms and organized as
shown in Fig.1[1].

![MAC Frame Structure](image)

Fig.1. Basic MAC frame structure for HIPERLAN/2

- BCH(Broadband CHannel : downlink) : conveys broadcast control inform-
  ation concerning the whole radio cell.
- FCH(Frame CHannel : downlink) : contains the information defining how
  the resources are allocated in the current MAC frame.
- ACH(Always CHannel : downlink) : informs the MTs that have
  used the RCH in the previous MAC frame about the result of their access
  attempts.
- RCH(Random access CHannel) : is defined for the purpose of giving an MT
  the opportunity to request transmission resources in the uplink MAC frames.
  The number of RCHs of one MAC frame is in [1,3] [1].
- DL(DownLink), UL(UpLink), DiL(Direct Link)

2.2 The previous schemes for the RCH allocation

The access to RCHs will be controlled by a contention window \( CW_a \) maintained
by each MT. Each MT decides \( CW_a \) by the number \( a \), where \( a \) is the number of
retransmission attempts made by the MT. The $CW_n$ is defined as follows, where $n$ is the number of RCHs in the current MAC frame \[1\].

$$\begin{align*}
\text{Initial attempt :} & \quad a = 0, \quad CW_0 = n \\
\text{Retransmission :} & \quad a \geq 1, \quad CW_a = \begin{cases} 256 & 2^a \geq 256, \\ 2^a & n < 2^a \leq 256, \\ n & n \geq 2^a. \end{cases}
\end{align*}$$

The RCH used for the $a^{th}$ retransmission attempt including an initial transmission ($a = 0$) will be chosen by a uniformly distributed random integer value $r$ within the interval $[1, CW_a]$. The MT shall start counting $r$ from the first RCH in the MAC frame, in which the ACH indicates the failure of the previous access attempt. For initial transmission, the MT starts counting with the first RCH in the current frame. The MT shall not access the RCH before its counter has reached the RCH with the number equal to $r$. After receiving the ACH with a positive feedback, $a$ will be reset to 0.

In \[3\], the number of RCHs is adaptively changed by the result of access attempts within the previous MAC frame. That is, the AP increases RCHs of next MAC frame as many as collided RCHs and decreases them by successful access attempts with weighting factor $a$. When there is no access attempt in the previous MAC frame, the AP reduces RCHs of the upcoming frame by one. The throughput of \[3\] can be increased to 37% when compared with fixed RCHs allocation schemes that perform at maximum 35% of channel throughput. This algorithm updating the number of RCHs is given by

$$r(t + 1) = r(t) + \alpha(\gamma(t) - \mu(t))(1 - \lambda(t)) = I_d(t)$$

where meanings of variables are as follows:

- $r(t)$ : the number of allocated RCHs at MAC frame $t$
- $\alpha$ : weighting factor
- $\gamma(t)$ : the number of collided RCHs at MAC frame $t$
- $\mu(t)$ : the number of successful RCHs at MAC frame $t$
- $I_d(t)$ : indication function of which value is 1 if there is no access attempt RCHs at MAC frame $t$; otherwise its value is 0

Constrain the scope of allowable number of RCHs per MAC frame from minimum one to maximum $R_{\text{MAX}}$ as Eq.4

$$r(t + 1) = \min\{\max\{r(t + 1), 1\}, R_{\text{MAX}}\}$$

3 New Random Channel Allocation Scheme

The AP controls the number of RCHs based on the splitting algorithm \[9\], by which the set of user involved in a collision is split into smaller subsets until
individual users are singled out, and then can transmit without the risk of a collision. The number of RCHs of \((t + 1)^{th}\) MAC frame is given by

\[
\begin{align*}
    r(t + 1) &= \min\{N_a + 2 \times N_f(t), R_{MAX}\} \\
\end{align*}
\]

where

- \(r(t)\) : the number of allocated RCHs at MAC frame \(t\)
- \(N_f(t)\) : the number of collided RCHs at MAC frame \(t\)
- \(N_a\) : the fixed number of RCHs allocated for newly arriving packets

As shown in Fig. 2, there are \(N_a\) RCHs for newly arriving request packets in each frame. For each collided RCH in the previous frame, additional two RCHs are allocated for collision resolution. For initial attempt, an MT randomly accesses one RCH within the interval \([1, N_a]\) as Eq. 6. The collided MTs in the previous MAC frame choose the RCH to access based on the location information of contention slots where collisions occur. That is, the MTs in the \(i^{th}\) RCH among the collided RCHs in the previous MAC frame randomly access either \((2 \times i - 1 + N_a)^{th}\) or \((2 \times i + N_a)^{th}\) RCH as Eq. 7. In addition, if there are not enough RCHs in the current MAC frame, the retransmission occurs within the interval \([1, N_a]\) after a random delay\(^1\) by frame unit as Eq. 8.

\[\text{\(\diamond\) Initial attempt: Random access within \([1, N_a]\)}\]

\[\text{\(\diamond\) Retransmission:}
\]

\[
\begin{align*}
    \text{Random access either } 2i - 1 + N_a \text{ or } 2i + N_a & \quad \text{if } 2i + N_a \leq R_{MAX} \\
    \text{Random access within } [1, N_a] \text{ after a random delay} & \quad \text{if } 2i + N_a > R_{MAX}
\end{align*}
\]

where \(i\) is the location of collided RCH in the previous MAC frame.

Fig. 2 shows an example of how the number of RCHs would be decided by the splitting algorithm, in which the number of RCHs for new requests is two and \(R_{MAX}\) is eight. If four RCHs are collided in the previous MAC frame, the number of RCHs will be 10 in the current MAC frame (two RCHs for new requests and eight RCHs that are split by four collided RCHs). However, the number of RCHs in the current MAC frame should be eight because \(R_{MAX}\) value is eight.

In the current MAC frame, new MTs can access the first or second RCH. The MTs collided on \(C_1\) of the previous MAC frame randomly access either \(C_{11}\) or \(C_{12}\). Similarly, the MTs involved in \(C_2\) in the previous MAC frame can randomly access either in the fifth or in the sixth RCH in the current MAC frame. However, the MTs involved in \(C_4\) in the previous MAC frame cannot access the RCH in the current MAC frame because the maximum number of RCHs is eight. Therefore, these MTs should access RCHs for new MTs after a random delay.

\(^1\) When collided requests cannot be transmitted in the next frame, due to lack of RCHs, the requests are scheduled after a random delay uniformly distributed in \([RT_{min}, RT_{max}]\) in frames. These request are treated as if they are newly arriving requests.
4 Simulation Results

This section presents some simulation results on the throughput, average delay and delay variance. In order to observe the presented performance issues, we examine the effects of the fixed number of RCHs allocated for new requests, $N_a$, and random delay experienced by MTs that should choose the RCHs out of the current MAC frame because there are not enough RCHs. The throughput ($\rho$) is defined as [3]

$$\rho = \frac{\text{total number of successful requests}}{\text{total number of RCHs allocated}}$$  \hspace{1cm} (9)

For simulation, we assume that there is no transmission error due to radio channel environment, there are 50 MTs as a whole, and each MT's resource request message is generated according to Poisson process with rate $\lambda$ per MAC frame. We also assume an MT cannot generate a new request message until the access attempt succeeds. We have simulated during 1000 seconds which contains $5 \times 10^5$ MAC frames.

In Fig. 3, we observe that the maximum throughput of the proposed scheme is 44%, while that of [3] is 37% when the weighting factor ($\alpha$) in Eq. 3 is one. In general, when the packet arrival rate is low, the higher throughput can be achieved when $N_a$ is low. That is, allocating many RCHs for new requests is a waste of resources when packet arrival rate is low. When the packet arrival rate is high, throughput can be improved when $N_a$ is high. It is demonstrated that the system throughput can be reduced by increasing the number of collided requests in the case of allocating a few RCHs for new requests when the packet arrival rate is high.

Fig. 3 also shows the effects of random delay experienced by MTs that should choose the RCH out of the current MAC frame when $R_{\text{MAX}}$ is 31. There is little difference in random delay (between 17 and 24 frames; between 25 and 32 frames) for the same value of $N_a$. The reason is that there are few occasions that the number of requested RCHs exceeds $R_{\text{MAX}}$ in the system in the case when $R_{\text{MAX}}$ is 31.
Fig. 3. Offered load versus throughput ($R_{\text{MAX}} = 31$)

Fig. 4 shows the throughput-delay characteristics of the proposed scheme. For example, the proposed scheme shows the delay within one frame when throughput is 3.5, however, the previous scheme [3] shows the delay beyond three frames. Concerning real-time traffic, the delay variance is also an important performance issue. Table 1 shows the delay variances of the previous work [3] and the proposed scheme. The proposed scheme performs well when compared with previously proposed schemes in terms of the mean delay and the delay variance. The future wireless LAN should guarantee QoS of not only non-real-time traffic but also real-time traffic, that is, QoS of multi-media traffic. Therefore, we can expect that the proposed scheme can be useful in guaranteeing QoS of multi-media traffic in wireless LAN.

Fig. 4. Throughput versus Mean delay ($R_{\text{MAX}} = 31$)
Table 1. Comparison of delay variances of [3] and the proposed scheme

<table>
<thead>
<tr>
<th>Arrival rate</th>
<th>[3] when $\alpha = 1$</th>
<th>Proposed scheme when $N_a = 2$, $R_{\text{MAX}} = 31$, Random delay=[17,24]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.02</td>
<td>1969.09</td>
<td>1.93806</td>
</tr>
<tr>
<td>0.03</td>
<td>1871.38</td>
<td>2.46129</td>
</tr>
<tr>
<td>0.04</td>
<td>1506.57</td>
<td>2.76634</td>
</tr>
<tr>
<td>0.05</td>
<td>1203.47</td>
<td>2.96508</td>
</tr>
<tr>
<td>0.105</td>
<td>484.129</td>
<td>3.38835</td>
</tr>
<tr>
<td>0.205</td>
<td>223.639</td>
<td>3.47065</td>
</tr>
<tr>
<td>0.305</td>
<td>150.943</td>
<td>3.5624</td>
</tr>
</tbody>
</table>

We have observed that the various random delay of MTs that exceeds $R_{\text{MAX}}$ has little effect on the system performance when $R_{\text{MAX}}$ is 31. However, when $R_{\text{MAX}}$ is relatively small, random delay becomes a critical variable on the system performance. In Fig. 5, we see the effects of small $R_{\text{MAX}}$, that is, when $N_a$ is 2 and $R_{\text{MAX}}$ is 8. Even if the maximum throughputs associated with the various random delay approaches 44%, the system falls into an unstable state when random delay takes values from the range of 1 to 10 or 1 to 16. Therefore, we can expect that the system performance may be improved by increasing random delay rather than by increasing the range of random delay.

Fig. 5. Offered load versus Throughput ($R_{\text{MAX}} = 8$)
5 Conclusion

In this paper, we proposed a new random channel allocation scheme of HIPERLAN/2 using the splitting algorithm. This scheme can reduce the complexity of MT because each MT does not need to maintain the retransmission attempts time and contention windows, and in addition, performs well in terms of throughput, mean delay and delay variance compared with the previously proposed RCH allocations schemes. From simulation results, we see that the throughput of our scheme is improved about 10% when compared with the fixed RCHs allocation scheme and the previous scheme[3]. In addition, we observed the effects of various random delay of MTs that exceeds the maximum number of RCHs and the number of reserved RCHs for new requests in a frame. For improving the throughput, the number of RCHs for new requests should be increased according to the traffic load. We also observed that the bigger random delay the better throughput.

The future wireless LAN should guarantee QoS of multi-media traffic. That is, in order to guarantee QoS for both non-real-time and real-time traffic, lowering delay and delay variance are needed for real-time traffic. Therefore, the proposed scheme can be applied for guaranteeing QoS of multi-media traffic in wireless LAN.

References

6. A. Dufexi et al., “Throughput Performance of WLANs Operating at 5GHz Based on Link Simulations with Real and Statistical Channels”, IEEE VTC ’01 Spring