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| Project | **IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>** |
| Title | **MAC Headers Structure for 802.16 MAC** |
| Date Submitted | **2001-01-17** |
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| Re: | This document is submitted in response to IEEE 802.16 Task Group 1 Call for Comments on IEEE 802.16.1/D1-2000 and Task Group 3 Call For Contributions: Proposed MAC Enhancements, Key Characteristics, and Evaluation Criteria: Session #11 |
| Abstract | This document figures the changes needed in the MAC header format of the TG1 MAC to reach the high flexibility needed for further development in the direction of TG1, TG3, TG4 |
| Purpose | The document is submitted within the 802.16 MAC development process, including the issue of TG1 MAC accommodation for TG3, TG4 |
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# MAC Headers Structure for 802.16.4

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## 1. References

[1] IEEE 802.16.1/D1 - 2000, December 2000. Draft Standard for Air Interface for Fixed
[2] IEEE 802.16p-00/10. Some Issues of Accommodation of TG1 MAC at TG3. By Vladimir Yanover
[3] IEEE 802.16.3p-00/56.Using the TG1 MAC for the TG3 Purposes. V.Yanover, S.Varma, H.Ye
[4] IEEE 802.16.3-01/XX. Reservation Tools for the 802.16.3 MAC. Naftali Chayat, Vladimir Yanover
[5] IEEE 802.16.3-01/XX. "Data Integrity in 802.16.3 MAC Naftali Chayat, Vladimir Yanover, Inbar Anson
[6] Subir Varma. Comments on the use of the TG1 MAC for TG3 Purposes. IEEE 802.16.1c-00/11

## 2. Acronyms

| | |
|---|---|
| **ARQ** | Automatic Repeat Request |
| **CS PDU** | Convergence Sublayer PDU |
| **DA** | Discard Acknowledgement |
| **DL** | Downlink |
| **FC** | Frame Control (field in MAC header [2]) |
| **FSN** | Fragment Sequence Number |
| **MPDU** | MAC PDU |
| **MSDU** | MAC Service Data Unit , i.e. CS PDU |
| **MSN** | MAC PDU Serial Number |
| **PDU** | Protocol Data Unit |
| **UL** | Uplink |

## 3. Problems

Today we are not certain about the functions we want to cover by the 802.16 MAC Header fields. This concerns mainly TG3 and TG4: concatenation of the payloads, ARQ, advanced QoS signaling, PHY related signaling, etc. But for the long run it is correct also for TG1 (note the massive changes entering now the 802.11, a year after the release of the 1999 version).

So we need to reserve a space for making detailed decisions later.

# 4. Proposed Solution

The solution proposed is to employ more flexible MAC header format. "Flexible" means that different types of messages may differ in length and the set of fields included.

It is suggested to keep the first portion of the MAC header of the fixed format so that the PHY Convergence (former Transmission Convergence) layer operations would be easier for HW implementation. This portion is protected by HCS.

All the rest of fields are placed after the HCS and form actually a single body with the MAC payload. Actually this was already done in the recent draft with the ARQ Control Field.

All the other fields are divided into a small number of groups (e.g. EC+ EKS+ FC + FSN + CSI + PDE relevant only to Data messages) and make the presence of the whole group dependent on the Type value.

Note that the idea of the invocation of the “Type” filed appears also in [6]. The Type value in [6] defines the encoding of the further bits while the format of Data message remains constant.

# 5. General MAC Message Format

## 5.1. Constant Part of the MAC Header

The following is the general MAC message format.

| | | | |
|---|---|---|---|
| Constant part of MAC Header | Variable part of MAC Header | MAC Payload | CRC (optional) |

The constant part of MAC Header contains the following fields

| Field | Size, bits |
|---|---|
| Type | 5 |
| Length | 11 |
| CID | 16 |
| HCS | 8 |

## 5.2. The Variable Part of the MAC Header

The variable part of the MAC Header contains the following zones (all optional):

| Zone | Contains the Fields<br>(If not specified, the size of a field the same as in [1]) | Fixed / Variable Size |
|---|---|---|
| **Data Control** | EC, EKS, FC, FSN, PDE, CI | Fixed |
| **CS PDU Identification** | CS PDU Serial Number and Retry Number | Fixed |
| **GM** | GM field, like in the existing draft, but with an additional option of the request field enlarged to 16 bits.<br>Two options exist, short = 8 bits (like in [1]) and long = 16 bits | Fixed |
| **AFB (ARQ Feedback)** | One or several ARQ Feedback records and/or ARQ Discard Records | Variable |

## 5.3. ARQ Feedback / Discard Info Format

ARQ Feedback Zone Structure consists of Discard Acknowledgement (DA) records and ARQ Feedback (AFB) records [5].

In the tables below **CID** means the Connection ID where the data was transferred, **Last** = '1' marks the last AFB / DA in the MAC Message.

The transmitter MAY inform the receiver on the discard decision by sending the discard acknowledgment (DA). Such an acknowledgment should be sent as a part of MAC message through the same connection as the data itself. DA has the following format:

**Table 1. DA Format, total = 16 bits**

| CID | Last | Mode = 101 | SerNo |
|---|---|---|---|
| 16 | 1 | 3 | 12 |

This record means that all the MSDUs with the serial numbers < **SerNo**. were discarded by the transmitter. The opposite side MAY answer to this information by sending the Medium AFB with the same Serial Number value.

The ARQ feedback fields (AFB) are used for encoding the results of integrity check performed on the MPDUs. These fields are to be inserted into the MAC messages transferred in the direction opposite to the direction of the connection. The ARQ feedback is transferred using one or several AFB records. The AFB record has the following formats: **Short, Medium, Long**:

**Table 2. AFB Short Format, total = 8 bits**

| Last | Mode | Reserved |
|---|---|---|
| 1 | 3 | 4 |

**Table 3. AFB Medium Format, total = 32 bits**

| CID | Last | Mode | SerNo |
|---|---|---|---|
| 16 | 1 | 3 | 12 |

**Table 4. AFB Long Format, total = 48 bits**

| CID | Last | Mode | SerNo | Mask |
|---|---|---|---|---|
| 16 | 1 | 3 | 12 | 16 |

Bits in the **Mask** correspond to either CS PDUs or fragments where the value '1' means a positive acknowledgement.

**Mode** defines the meaning of another sub-fields:

| Mode value | Meaning | AFB Format |
|---|---|---|
| 000 | Appears in AFB Short format only. Being used by the SS, this AFB means that this SS has successfully received all the DL MAC headers within the latest frame and all the MAC messages addressed to the given connection were received successfully<br>Being used by the BS, this AFB means that the BS has successfully received all the UL MAC headers from the given SS within the latest frame and all the MAC messages addressed to the given connection were received successfully | Short |
| 001 | The **SerNo** value means that all the MSDUs with all the serial numbers < **SerNo** were successfully received | Medium |
| 010 | The **SerNo** value defines the interval M…M+15 of the serial numbers (MSN) of the consecutive MSDUs. The acknowledgements for these MSDUs are provided by the correspondent **Mask** bits | Long |
| 011 | The value **SerNo** means the MSN of the fragmented MSDU so that the acknowledgements for the fragments are provided by the correspondent **Mask** bits | Long |
| 100 | Same as above plus indication that all the serial numbers < **SerNo** were successfully received. | Long |
| 101 | ARQ Discard Record | |
| 110-111 | Reserved | |

Thus the AFB record may contain 1, 4 or 6 bytes. The most typical is to use a single 1 byte AFB with Mode = 000 per connection so the overhead of acknowledgments is considerably small. See more details in [5].

## 6. MAC Message Types

The following is the list of possible types

- Data DL (with the option of piggybacked AFB/DA info)
- Data UL (with the option of piggybacked GM and AFB/DA info)
- BW Request (with the option of piggybacked AFB/DA info)

- Management

There is no separated type for ARQ acknowledgement.

Each of these types has certain set of fields as defined by the following table.

**Note.** The CSU PDU Identification field is present if and only if the ARQ is enabled for this connection.

| Message function | Type | Data Control | GM Short | GM Long | AFB / DA |
|---|---|---|---|---|---|
| Management DL | 0 | - | - | - | X |
| Management UL | 1 | - | - | - | X |
| Management UL | 2 | - | - | X | X |
| Data DL | 3 | X | - | - | - |
| Data DL | 4 | X | - | - | X |
| Data UL | 5 | X | - | - | - |
| Data UL | 6 | X | - | - | X |
| Data UL | 7 | X | X | - | - |
| Data UL | 8 | X | X | - | X |
| Data UL | 9 | X | - | - | - |
| Data UL | 10 | X | - | - | X |
| Data UL | 11 | X | - | X | - |
| Data UL | 12 | X | - | X | X |
| BW Request | 13 | - | - | X | - |
| BW Request | 14 | - | - | - | X |
| Reserved | 15-31 | | | | |

Therefore this scheme needs total 15 type values of total 32 possible. The rest of them are reserved.

## 7. Examples

This paragraph figures several possible formats of MAC messages. In these examples the constant format portion (obligatory) is marked green, data control portion - brown, AFB/DA specific portion – blue, Grant Management – yellow, ARQ feedback – magenta. The presence of each portion is defined by the Type field and / or the fact that ARQ is enabled/disabled for the given connection.

A comparison provided with the overhead added by the existing formats [1].

**Example #1**
Type = Data UL + ARQ Disabled + piggybacked short GM + no piggybacked AFB/DA

Note that the UL Data message header is still of 8 bytes length as in [1]. So actually there is no or little difference between this case and existing header format.
This format might be defined obligatory, others optional etc.

Note also that the GM may not be present in all the UL messages and then we have header of only 7 bytes.

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Constant Format portion | Type | | | | | | Length | |
| | Length-cont. | | | | | | | |
| | CID | | | | | | | |
| | CID-cont | | | | | | | |
| | HCS | | | | | | | |
| Data Control | EC | EKS | | CSI | CI | FC | | PDE |
| | FSN | | | Reserved | | | | |
| Grant Management | GM | | | | | | | |
| MAC Payload | CS PDU Data | | | | | | | |
| CRC | CRC | | | | | | | |
| | CRC-cont. | | | | | | | |
| | CRC-cont. | | | | | | | |
| | CRC-cont. | | | | | | | |

**Example #2**

Type = Data UL + ARQ Enabled + piggybacked long GM + piggybacked AFB/DA

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Constant Format portion | Type | | | | | Length | | |
| | Length-cont. | | | | | | | |
| | CID | | | | | | | |
| | CID-cont. | | | | | | | |
| | HCS | | | | | | | |
| Data Control | EC | EKS | | CSI | CI | FC | | PDE |
| | FSN | | | Reserved | | | | |
| CS PDU Identification | Retry count | | | | Sequence Number | | | |
| | Sequence Number-cont. | | | | | | | |
| Grant Management | GM | | | | | | | |
| | GM-cont. | | | | | | | |
| DA Record | CID | | | | | | | |
| | CID-cont. | | | | | | | |
| | **Last = 0** | Mode | | | Reserved | | | |
| AFB Record | CID | | | | | | | |
| | CID-cont | | | | | | | |
| | **Last = 1** | Mode | | | SerNo | | | |
| | SerNo-cont. | | | | | | | |
| | Mask | | | | | | | |
| | Mask-cont. | | | | | | | |
| MAC Payload | CS PDU Data | | | | | | | |
| CRC | CRC | | | | | | | |
| | CRC-cont. | | | | | | | |
| | CRC-cont. | | | | | | | |
| | CRC-cont. | | | | | | | |

**Example #3**
Type = BW Request with long GM

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Constant Format portion | Type | | | | | Length | | |
| | Length-cont. | | | | | | | |
| | CID | | | | | | | |
| | CID-cont. | | | | | | | |
| | HCS | | | | | | | |
| Grant Management | GM | | | | | | | |
| | GM-cont. | | | | | | | |
| CRC | CRC | | | | | | | |
| | CRC-cont. | | | | | | | |
| | CRC-cont. | | | | | | | |
| | CRC-cont. | | | | | | | |

The same fields as in [1] are present and the size of the correspondent part is 7 bytes (as in [1]), but here is an additional CRC overhead thus resulting in 11 bytes. Note that this format allows for adding ARQ feedback records. To decrease the overhead, a shortened format may be proposed:

**Example #4**
Type = Shortened BW Request

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Type | | | | | BR | | |
| BR-cont. | | | | | | | |
| CID | | | | | | | |
| CID-cont. | | | | | | | |
| HCS | | | | | | | |

Note that this message requires only 5 bytes, but in the price of replacing Length with BR that makes an exception in encoding of the first header portion.