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Title	OFDMA\OFDM Considerations in TG3 and TG4	
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Re:	This contribution is an input for the TG3 and TG4 MAC sub-group draft documents.	
Abstract	This contribution describes the MAC-PHY considerations and information exchange needed for support OFDMA/OFDM based PHY layer.	
Purpose	Input contribution for the TG3 and TG4 MAC draft.	
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OFDMA\OFDM Considerations in TG3 and TG4

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Introduction

This contribution describes the MAC-PHY considerations and information exchange needed for support OFDMA/OFDM based PHY layer.

The OFDMA access scheme presented in [1] defines an access scheme of a two dimensional grid that combines time and frequency division access technique.

The 802.16.1 MAC layer needs to be enhanced\updated to support OFDMA\OFDM access scheme while saving the main working principles of the MAC layer.

In a MAC protocol that supports OFDMA PHY layer (like one presented in [1]), the concept of a sub-channel should be supported, as presented in [4], mini-slot duration should last for the time duration of a full OFDM symbol and should be used as a time symbol reference. In addition, for each time symbol reference, a sub-channel reference should be provided for an OFDMA access resolution.

Each of the Uplink and Downlink symbols are built from subcarriers, which are divided statically into *sub-channels* that are groups of 53 (48 useful carriers). A sub-channel does not necessarily contain consequent subcarriers.

The OFDMA defines a slot as a pair $\{N,m\}$ that represents a combination of an OFDM time symbol (N) and number of a sub-channel (m).

In each cell a single FFT size is used

Basic Parameters

This section defines OFDMA related basic terminology and relevant parameters.

Region and PHY Burst

For both Uplink and Downlink transmissions, several consequent sub-channels may be aggregated for several consequent symbol duration intervals (OFDM Symbols). Such an aggregation is figured by a rectangle **Region** at the Subcarrier(frequency)-Time domain.

Figure 1 illustrates an allocation pattern instance of a Region:

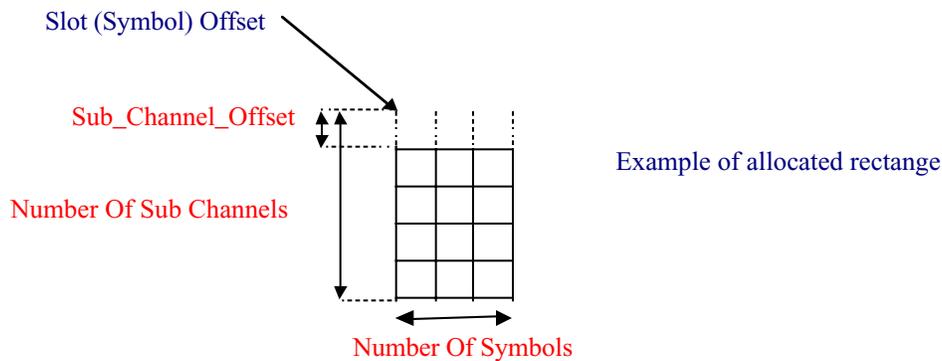


Figure 1. Example of a Two dimensional Pattern

A Region can be assigned in the UL to a specific SS (or a group of subscribers) or can be transmitted in the DL by the BS as a transmission to a (group of) SS.

The SS's transmission at the Region is called **PHY Burst**.

The BS's transmission at the Region is called **DL PHY Burst**.

UL Transmission

The PHY Burst properties will be figured:

- In the MAC-PHY interface primitives
- In UCD message within Burst Profile TLV encodings
- In UL-MAP message, implicitly identified by UIUC.

The BS learns each of SS's specific working parameters (during the SS's UL maintenance Ranging and data transmission) and assigned internally UL PHY Burst profile for each SS.

The parameters the BS uses are:

- The CIR of the channel (which can be achieved when using the CDMA synchronization approach [6])
- The C/n of the user (by measurement from a user message)

The basic suggested (partial) profiles for the uplink transmission can be summarized in the following table:

Profile	0	1	2	3	4	5	6
C/n dB	3-6	6-9	9-12	12-17	17-20	>20	
Modulation+ code Rate	QPS K 1/2	QPS K 3/4	QAM16 1/2	QAM16 3/4	QAM64 2/3	QAM64 3/4	reserved

The defined values are used for a reference, bad CIR can cause the BS to chose lower profile or allocation of fewer Sub-Channels enables the BS to choose higher profile.

The UL MAP IEs shall have the UIUC that represent the relevant profile that determined by the BS.

Figure 2 describes the logical structure of UL PHY Burst.

Note: for the next figures, the size (number of symbols) of the preamble is still under definition of the PHY group.

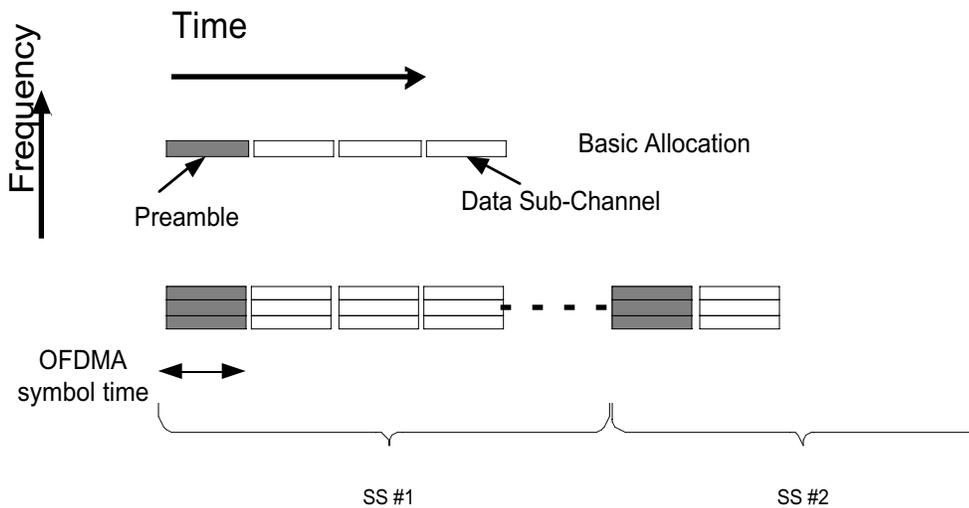


Figure 2. UL PHY Burst example

Figure 3 describes two different subscribers with different PHY Burst structures and profiles.

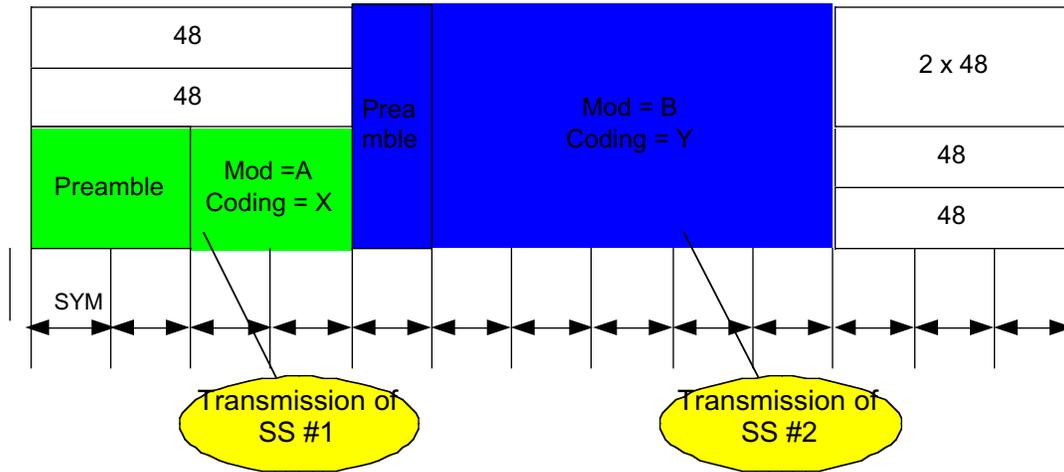


Figure 3. UL Burst Definition Example #1

Figure 4 describes two different subscribers with similar PHY Burst structure and with different profiles.

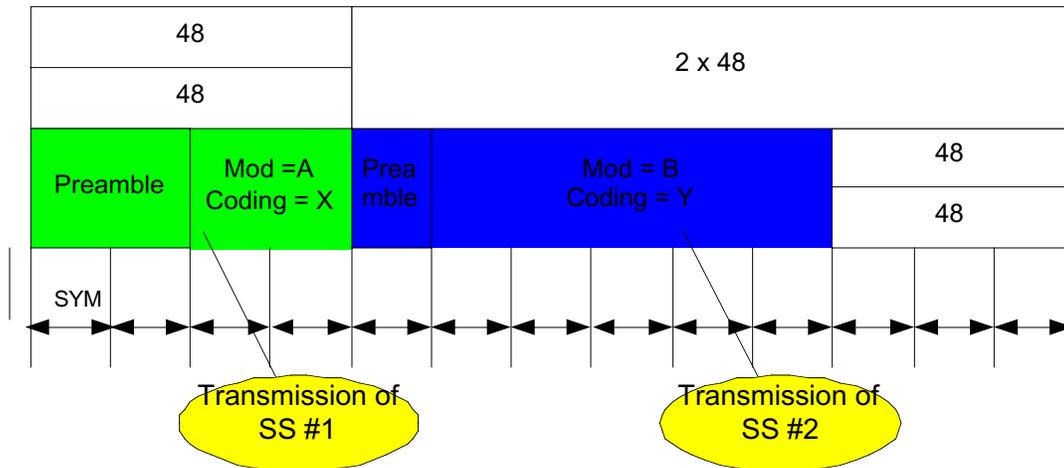


Figure 4. UL Burst Definition Example #2

DL Transmissions

The DL PHY Burst properties will be figured:

- In the MAC-PHY interface primitives
- In UCD message within Burst Profile TLV encodings
- In DL-MAP message, implicitly identified by DIUC.

- In the RNG-RSP or DBTC-RSP messages, implicitly identified by the Downlink Burst Type.

The set of DL PHY Burst parameters is specified in <Reference to OFDM PHY relevant section> and includes at least:

- Modulation type
- FEC type
- Tx Power

The forward adaptive profiles are relevant in the Bursty working modes (FDD-B and TDD).

The SS requests from the BS a specific DL PHY Burst type (using the DBTC-REQ or RNG-REQ messages), the BS will acknowledge the user with a downstream working mode (using the DBTC-RSP or RNG-RSP messages).

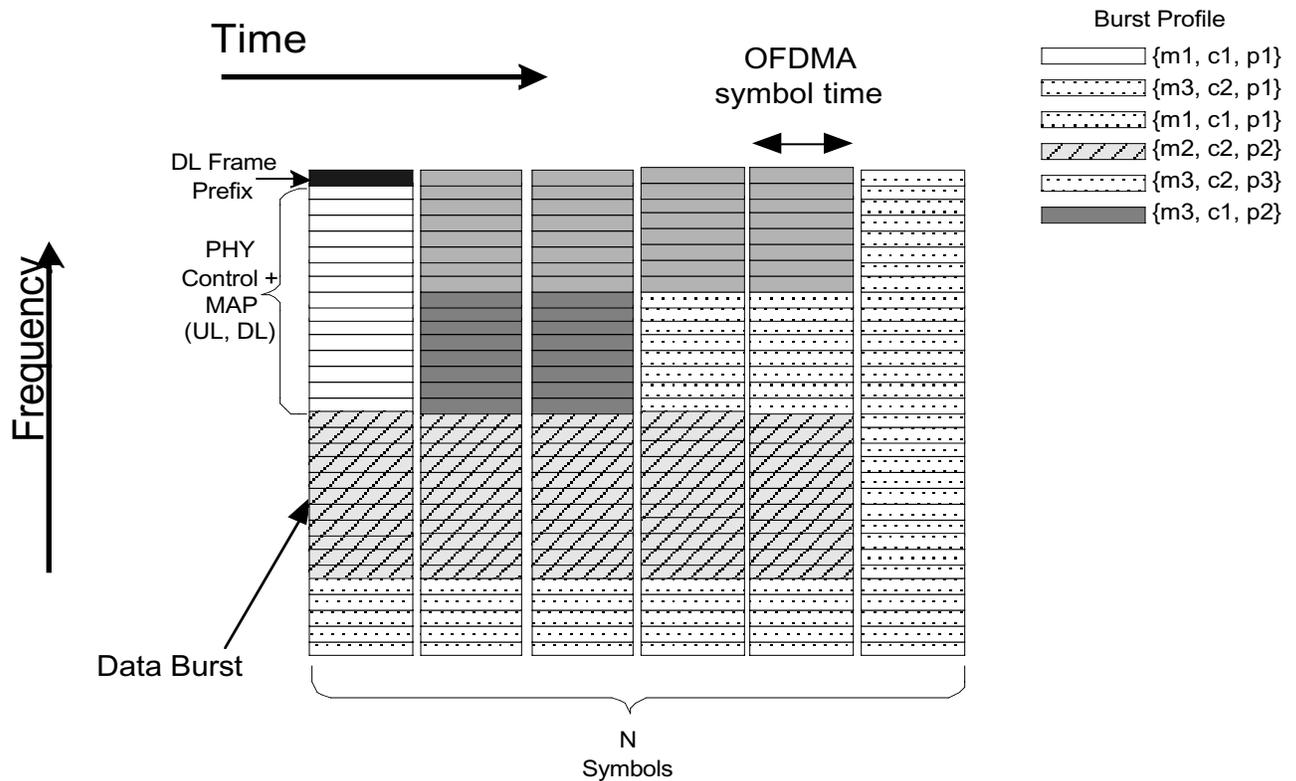


Figure 5. DL Period example #1

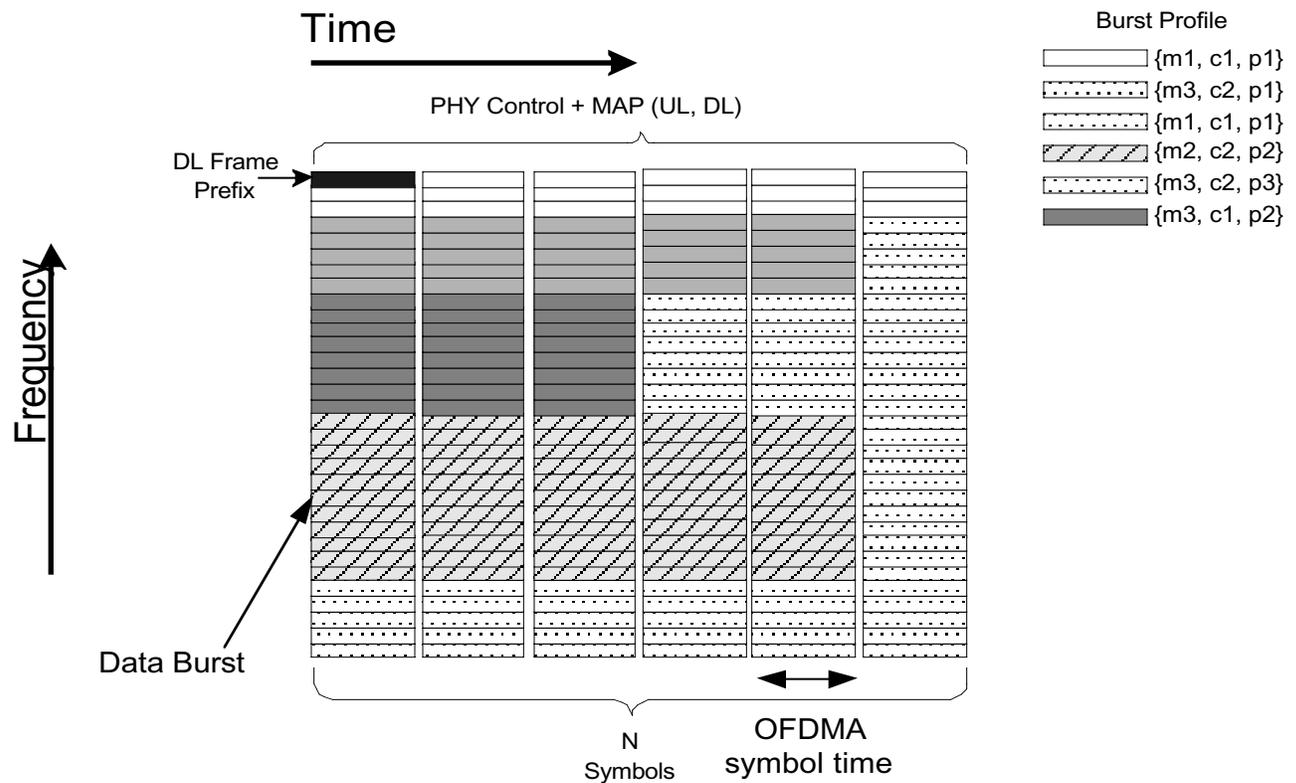


Figure 6. DL Period example #2

Figure 5 and Figure 6 describes two scenarios of DL OFDMA allocation with two options of sending DL MAP.

In the OFDM working modes (small FFT sizes), TDM\TDMA working model is used. This means that the unit of allocation is a full OFDM symbol. In those modes, the frame control information (DL\UL MAP) shall be sent on the first Symbol(s).

In the high FFT sizes modes, OFDMA working model is used. This means that the unit of allocation is a Burst (which is a combination of a sub-channels and time symbols). In those modes, there are two possibilities to transmit the DL\UL MAP:

1. To take advantage of the option of forward power control, and robust transmission of frame control information, the transmission of the DL\UL MAP can be done by using 1-2 sub-channels for the duration of the whole frame while power boosting the used carriers (see Figure 6).
2. To use the basic method of the OFDM case, but with size optimization. This means that the DL\UL MAP shall be transmitted at the beginning of the frame, using all or part of the sub-channels.

The frame control information should be transmitted in a deterministic pre-defined (and robust) configuration, therefore indication about the frame control information should be defined.

To be able to support a generic formation of frame control message in the downlink in the context of OFDMA\OFDM PHY modes, we propose the notion of *DL Frame prefix*.

DL Frame Prefix is one symbol long, it is transmitted at the well-known modulation/coding and occupies the well-known set of sub-carriers, e.g. the first $N \times 48$ (for the FFT-64 always $N = 1$, for FFT-256 OFDM always $N = 4$ or For FFT-2048 OFDMA always $N=1$ etc.).

It contains the information on the modulation/coding and formation of the DL frame control information (DL\UL MAP messages) relevant to the next frame or to the same frame.

Figure 7 describes the structure of DL Frame Prefix:

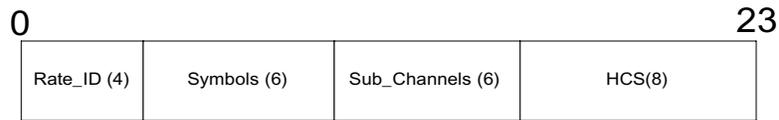


Figure 7. DL Frame Prefix Structure

Rate_ID: Enumerated field that describes the transmission parameters of the DL\UL MAP messages.

Symbols: Number of time symbols dedicated to the DL\UL MAP message.

Sub_Channels: Number of sub-channels dedicated to the DL\UL MAP message.

HCS: An 8-bit Header Check Sequence used to detect errors in the DL Frame Prefix. The generator polynomial is $g(D) = D^8 + D^2 + D + 1$

DL Frame Prefix can contain also MAP message(s) (for FFT-512 for example, the full first symbol will contain the DL Frame Prefix and beginning of the DL\UL MAP messages) and the “MAP” PHY burst may contain also the data.

For the lowest modulation it is exactly 3 bytes.

The Combination of the fields *Symbols* and *Sub_Channels* defines the structure of the MAP message and position (relative to the top left entry of the DL frame). In the small FFT cases (OFDM modes) *Sub_Channels* field will always indicate full OFDM symbol.

Proposed Modifications to the 802.16.1 MAC

In order to support a two dimensional allocation scheme, a pattern MAP IE should be defined using the basic structure presented in Figure 8:

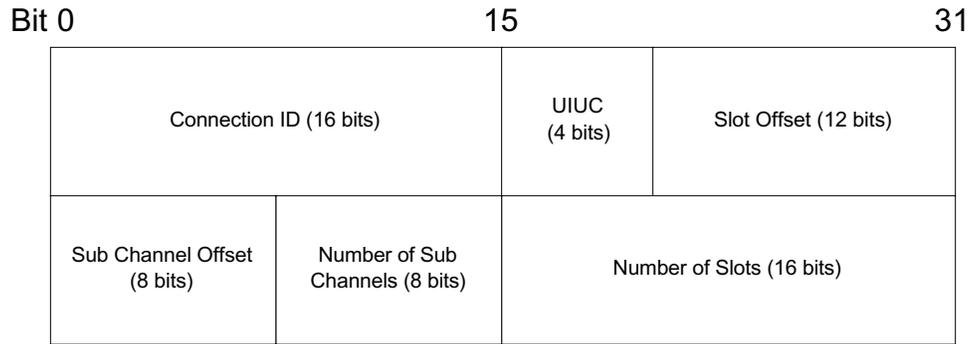


Figure 8. Two dimensional pattern MAP IE

The pattern MAP IE shall define a two-dimensional allocation pattern by using the following parameters:

Slot Offset: Provides an OFDM symbol time reference.

Sub Channel Offset: Provides Initial Sub Channel offset from the start of the OFDM symbol

Number of Sub Channels: Provides the “width” of the allocation pattern, i.e. the number of consecutive sub-channels used for this allocation pattern.

Number of Symbols: Provides the number of time Symbols to be used for the allocation pattern.

SS Rx HW Capabilities Parameters

The following Capability should be added to the SS’s Capabilities TLVs (chapter 11.4.5):

DL_PHY Bursts: describes the ability of SS to Rx simultaneously N PHY Bursts.

It is on BS (Scheduler’s) responsibility to avoid situation an SS is assigned at the DL more than N bursts.

DIUC\UIUC size

The DIUC and the UIUC sizes should be increased to be able to facilitate more Burst profiles. We support the proposal to increase the size of DIUC and UIUC to 5 bits in the following messages:

Take one bit from Slot_Offset\PS_Start in the UL_MAP\DL_MAP.

Take one bit from reserved bits in: DBTC-REQ, DBTC-RSP, DCD and UCD messages.

References

- [1] Y.Segal, Z.Hadad, I.Kitroser. Initial OFDMA Proposal for the 802.16.3 PHY Layer. January 2001.
- [2] IEEE 802.16.1/D2. Draft Standard for Air Interface for Fixed Broadband Wireless Access Systems. January 2001.
- [3] IEEE 802.16.3-00/02r4. Functional Requirements for the 802.16.3 Interoperability Standard. September 2000.
- [4] IEEE 802.16.4c-01/02. Modifications to the TG1 MAC for use in TG4 Systems. January 2001
- [5] DVB-RCT v.116 standard approved draft, April 2001.
- [6] IEEE 802.16.3c-01/54. OFDM based Ranging Enhancement for the TG3 and TG4. April 2001