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Re:	Call for Contributions: Proposed MAC Enhancements, Key Characteristics and Evaluation Criteria: Session #11, (TG3); issued 2000-12-23.
Abstract	This contribution proposed guidelines for enhancements to the 802.16.1 MAC when based on an OFDMA PHY layer.
Purpose	For consideration for inclusion in the proposed 802.16.3 MAC standard.
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Proposed Enhancements to 802.16.1 MAC to Accommodate OFDMA PHY

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1. Introduction

This contribution proposes guidelines for enhancements to the 802.16.1 MAC when based on an OFDMA PHY layer as proposed in [1].

An OFDMA based PHY layer presents several unique features that could be used to efficiently utilize the transmission media and improve the performance of the BWA system.

This proposal identifies some of those features and provides some guidelines of what changes required to the 802.16.1 MAC in order to use them.

2. Ranging Mechanism using CDMA Codes

Motivation

This section presents enhancements to the ranging procedure based on the PHY proposal in [1].
The goal of the enhancements is to use the advantages of the OFDM based PHY to facilitate simpler and safer initialization of the user with the base station.

Background

The upstream physical layer access method presented in [1] is based on the use of a combination of time and frequency division access technique.

The proposed synchronization technique is based on several sub carriers that are spread on the entire bandwidth and are collected in CDMA form. This allows several users to perform synchronization simultaneously, those special carriers are allocated for synchronization purpose and shall be referred as R*anging slots*.

The basic allocation unit (e.g. *slot*) is a combination of a time symbol and a sub-channel. [1] proposes several working modes, those modes defines two upstream access schemes:
1. Each OFDM symbol will carry either data or ranging slots
2. Each OFDM symbol will carry both data and ranging slots

Figure 1 and Figure 2 illustrates the concept of access scheme 1.

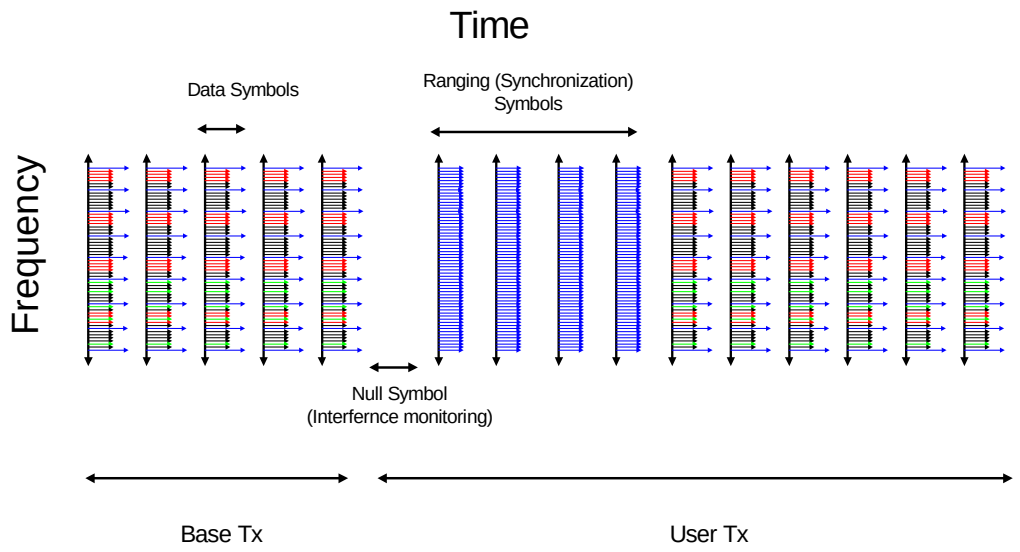

Figure 1. OFDM Symbols carrying either Ranging or Data slots – General Concept

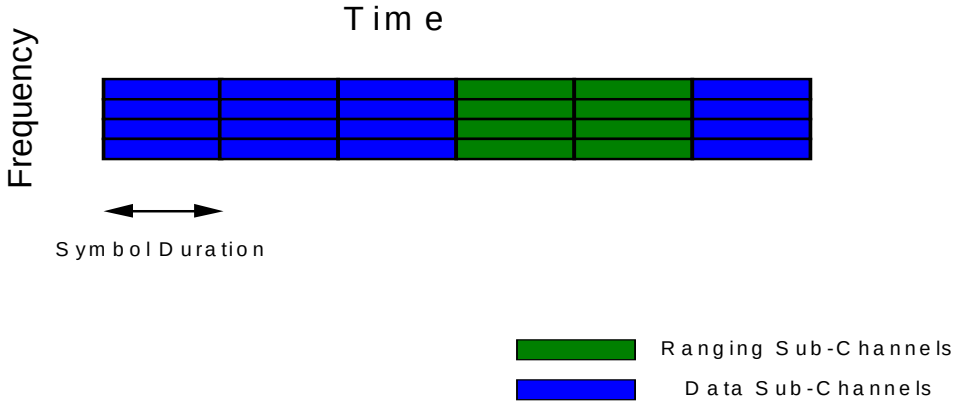

Figure 2. OFDM Symbols carrying either Ranging or Data slots in the 64 carriers mode

Figure 3 and Figure 4 illustrates the concept of access scheme 2.

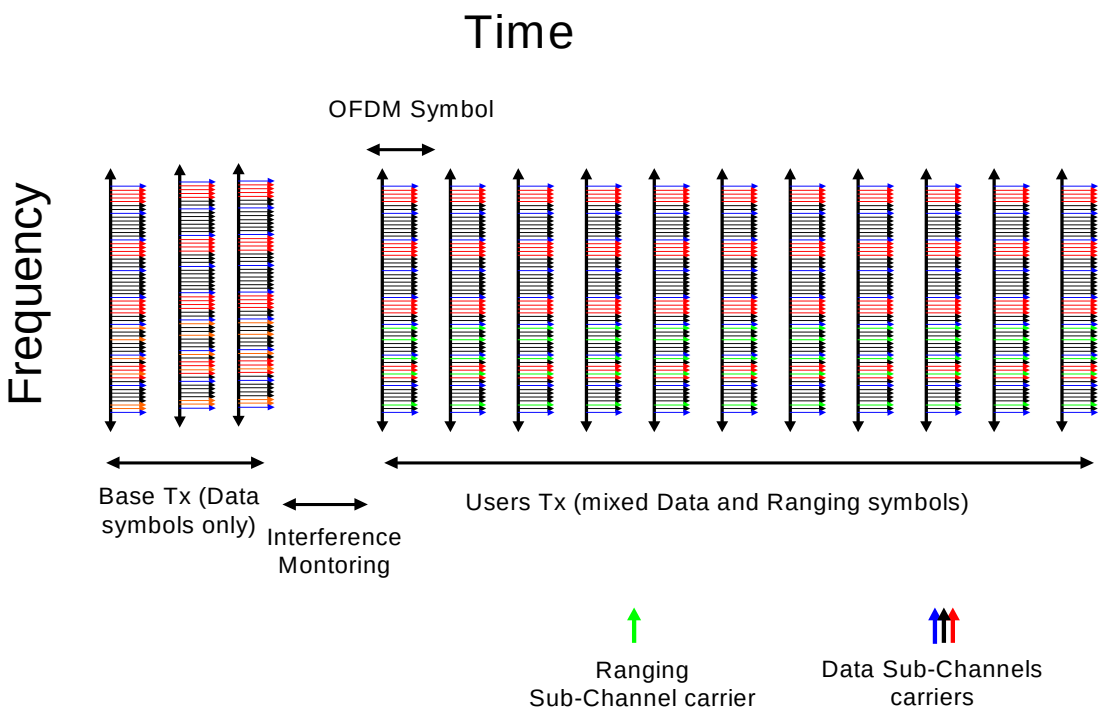

Figure 3. OFDM Symbols carrying both Ranging and Data slots – General Concept

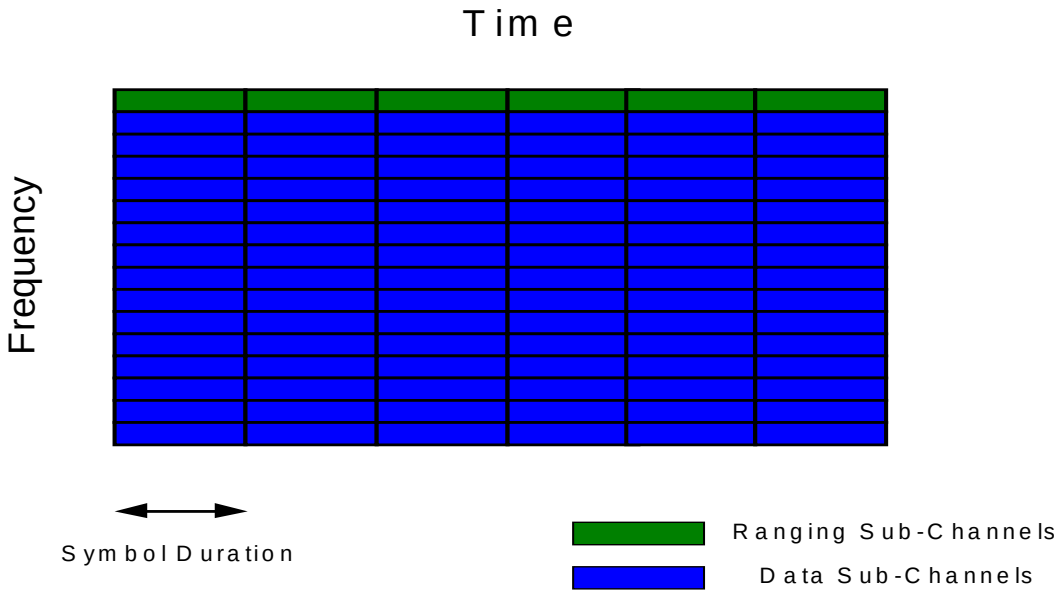

Figure 4. OFDM Symbols carrying both Ranging and Data slots in the 256 carriers mode

Each user that wants to perform ranging will choose randomly a PN sequence from a set of PN sequences and will modulate (with a pre-defined robust modulation scheme, i.e. BPSK) it on a pre-defined set of carriers. The randomly chosen PN is referred as *Ranging Code.*

In [1] three domains of Ranging Codes are defined, one shall be used for Initial Ranging, one shall be used for Maintenance Ranging and one for Bandwidth Requests (see section 3).

Proposed Ranging Overview

The ranging is the process of acquiring the correct timing offset such that the SS's transmissions are aligned to a symbol that marks the beginning of a burst(s) boundary.

The proposed ranging technique is mostly similar to the one presented in [2]:

The SS, after acquiring downstream synchronization and upstream transmission parameters, shall choose randomly a Ranging Slot (with use of a binary truncated exponent algorithm to avoid of possible re-collisions) as the time to perform the ranging, then it chooses randomly a Ranging Code (from the Initial Ranging domain) and sends it to the BS (as a CDMA code).

The BS upon successfully receiving a Ranging Code sends a Ranging Response message that addressed the sending SS by supplying the Ranging Code and Ranging Slot in the message.

The Ranging Response message contains all the needed adjustment (e.g. time, power and possibly frequency corrections) and a status notification.

Upon receiving Ranging Response message with continue status, the SS shall continue the ranging process as done on the first entry.

The main points of difference with the classical ranging process are:

In 1K and 2K carriers modes, a specific set of carriers shall be used for ranging, hence deduce that each OFDM symbol will contain a pre-defined and fixed ranging slot.
In 64 and 256 carriers modes, a full symbol(s) shall be used for ranging, this means that the base station shall define an Initial Maintenance region in the same way it defined in [2].
The entry to the system is anonymous and remains so for the whole ranging process, the SS is identified by the indication of the sent ranging slot and sent ranging code.
In the 1K and 2K carriers mode, the BS does not need to allocate a specific ranging region, this allow the SS to choose when to initiate the system entry.
Several SS can send ranging code simultaneously without colliding (due to the CDMA technique).

Proposed Modifications to the 802.16.1 MAC

The following section defines the modifications need to done to the 802.16.1 MAC in order to accommodate the proposed CDMA ranging technique assuming that the PHY layer supports the required features (e.g. ranging slots, ranging codes etc.)

Ranging region indication

For the 64 and 256 carriers mode, the ranging slots shall use full OFDM symbols, therefore the initial ranging interval shall be allocated in the same way it is done in [2].
For the 1K and 2K carriers mode, the ranging slots shall use one (or more) sub-channels of an OFDM symbol and will exists for each OFDM symbol, therefore no indication about initial maintenance region is required.

Update to 6.2.1.2.6 Section

The following addition should be done to the RNG-RSP Message description in section 6.2.1.2.6 line 15 page 58:
Ranging Slot: A required parameter if the SS used CDMA ranging code for initial ranging, in this case the RNG-RSP message will be sent using broadcast CID, and the combination of Ranging Slot and Ranging Code shall be used to address the sending SS.
Ranging Code: A required parameter if the SS used CDMA ranging code for initial ranging, in this case the RNG-RSP message will be sent using broadcast CID, and the combination of Ranging Slot and Ranging Code shall be used to address the sending SS.

Change to the RNG-RSP Message

The following TLV values should be added to the RNG-RSP message encoding table, section 11.1.4 page 294:

Table 1: RNG-RSP TLV Addition

Name	**Type** (1 byte)	Length (1 byte)	Value (Variable Length)
Ranging Slot	13	TBD	Used to indicate the OFDM symbol reference that was used to transmit the ranging code. This TLV is used in conjunction with the Ranging Code value to identify the sending SS.
Ranging Code	14	1	Used to indicate the ranging code that was sent by the SS (unsigned 8-bit). This TLV is used in conjunction with the Ranging Slot value to identify the sending SS.

3. Bandwidth Request using CDMA Codes

Motivation

To address [3] and special requirements of an IP centric environment, an option of a fast BW reservation mechanism is essential to cope with bursty and dynamic traffic.

The proposed mechanism take advantage of the OFDM based PHY as proposed in [1] to provide a CDMA code based bandwidth reservation tool.

Description of the proposed BW Request mechanism

As described in section 2 and in [1], several PHY configurations are proposed, especially, the 1K and 2K modes defines the concept of sub-channels as a subset of the frequencies transmitted in one OFDM symbol, those two modes define a unique ranging slots that co-exists with data slots for each OFDM symbol.
The SS may use the ranging slots to send CDMA codes from a three domains of codes (see previous section), the last domain shall be used for bandwidth requests, e.g. *Request Code*.

The proposed mechanism defines usage of the Request Code by the SS to request fast BW allocation on a bursty basis.

The SS, upon a need to request for transmission slots, shall access the air interface without the need to be polled and with reduced collision risk by transmitting a Request Code.
Several request codes sent by several SS can be transmitted simultaneously without collision (with limitation on the number of parallel codes).
The BS, when demodulating the ranging slots, and when receiving a request code, shall allocate a pre-defined (and configurable) number of bytes to the SS, the addressing of the allocation shall be done by attaching the indication of the Ranging Slot and Request Code.

The SS will use the unique allocation either to send small packet or bandwidth request.

The advantage of the proposed mechanism is the fairly safe polling indication by the SS and transmitting bandwidth request in a unique allocated slot, or the option for fast requests for small allocation that can be used to send small bursty based packets (like TCP Acks) in a highly dense cells.

Proposed Modifications to the 802.16.1 MAC

Request Code Grant Interval

When using the Request Code, the BS allocates a pre-defined number of slots to the sending SS whose Request code and Ranging slots are provided in the upstream MAP IE.
The value of such allocation is defined by the BS and can be optimizes according to the traffic behavior.
The minimum value of the grant interval should be big enough to accommodate at least upstream bandwidth request message.

New UIUC Addition

New UICU value should be added in order to identify allocation as reaction to Request Code.

The following UIUC value should be added to section 6.2.1.2.4 Table 4 page 55:

Table 2: Request Code UIUC value

IE Name	UIUC	Connection ID	Mini-slot Offset
Request Code Allocation	12	Broadcast	TBD

In this proposal, we adopt the Upstream MAP IE structure presented in [4] to provide enhancements with full backward compatibility.

Figure 5 shows the proposed Upstream MAP IE for the proposed new UIUC.

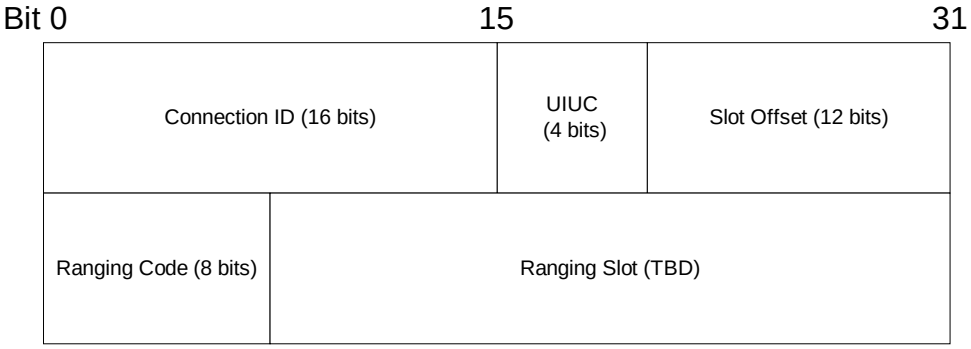

Figure 5. Proposed Upstream MAP IE structure for Ranging Code UIUC

4. Allocation Process

Motivation

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

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.

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).

The relation between normal TDMA approach and OFDMA approach is described in Figure 6:

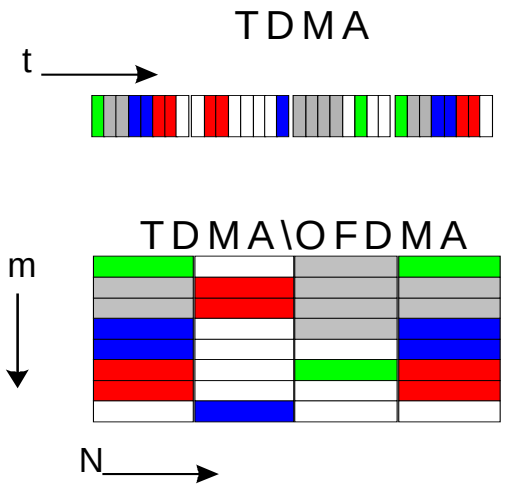

Figure 6. Correlation between TDMA and OFDMA

The MAC scheduler can directly transform the OFDMA model into a TDMA model as mentioned in [1].
This section proposed an enhanced allocation mechanism that takes into account the two dimensional scheme to provide allocation of slots that incorporate both time and frequency domains.

A two dimensional allocation scheme will allocate a set of sub-channels to the SS, those sub-channels can continue for more then one OFDM symbol while creating an allocated sub-grid.
The main advantage of such allocation scheme is to fully utilize the proposed OFDMA PHY system in order to facilitate all possible traffic requirements from users.

For example, allocating small set of sub-channels to one user over several time symbols will emulate a fixed rate allocation channel.
Another example is in downstream OFDMA scheme, when sub-channels will be grouped per FEC regions for several downstream symbols, this will allow parallel transmitting of different FEC blocks.

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 7:

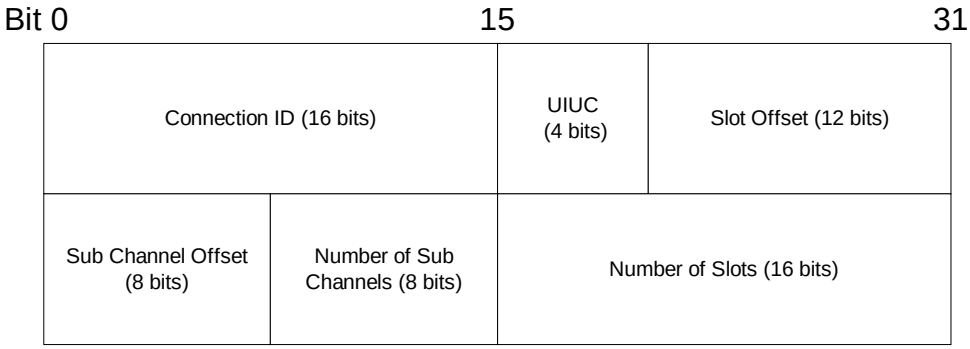

Figure 7. Two dimensional pattern MAP IE

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 slots: Provides the number of allocation slots to be used for the allocation pattern.

Figure 8 illustrates an allocation pattern instance:

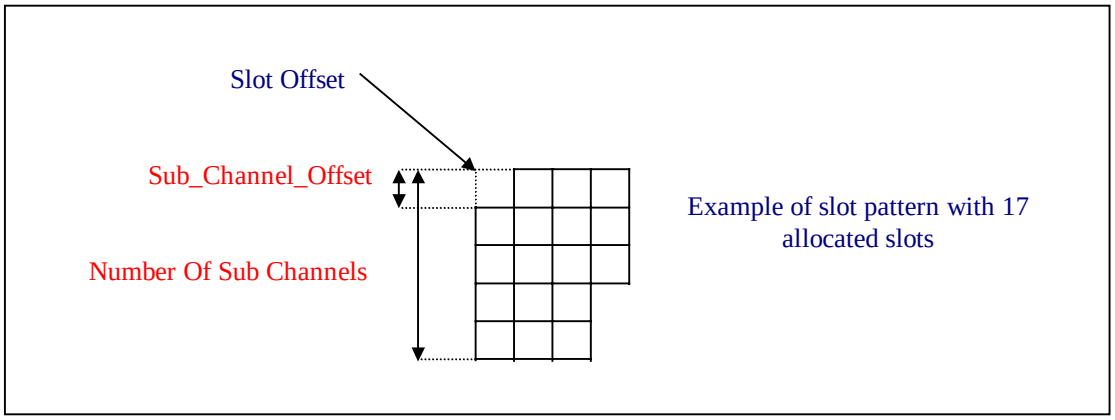

Figure 8. Example of a Two dimensional Pattern

The proposed allocation mechanism can be optimized when only one dimensional – TDMA like- allocation is needed (like suggested in Figure 2), in this case only the Slot Offset parameter is needed.

5. 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/D1. Draft Standard for Air Interface for Fixed Broadband Wireless Access Systems. December 2000.
[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 standard draft, October 2000.