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Re:	
Abstract	Suggests OFDMA topic for 802.16abc-01/01r1
Purpose	The document intended to the review by MAC-PHY Ad Hoc group
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OFDMA Updates to 80216ab-01_01r1 document

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General

This document presents modifications/updates and some additions to the OFDMA sections of the MAC working document.
The submission presents a suggestion to the OFDMA TOC and some text additions\updates to existing sections.

OFDMA TOC

The following TOC is a proposed TOC for the OFDMA PHY support, we took the basic TOC that was proposed for the OFDM section by Vladimir and tried to remove the possible common sections (like Mini-Slot definition, Synchronization field and MAP Relevance).
Also, we have noticed that the Preambles issue is not yet agreed by the PHY group and a content of such section is not very clear, therefore those sections were removed.

Hereby a proposed TOC for the OFDMA part of the MAC-PHY chapter:

8.3.4.4.1 OFDMA Basic parameters
8.3.4.4.1.1 OFDMA Slot Definition
8.3.4.4.1.2 Region and PHY Burst
8.3.4.4.2 OFDMA Frame Structure
8.3.4.4.2.1 MAP Messages
8.3.4.4.2.1.1 OFDMA Downlink MAP message
8.3.4.4.2.1.2 DL MAP Information Element Format
8.3.4.4.2.1.3 OFDMA Uplink MAP message
8.3.4.4.2.1.4 UL MAP Information Element Format
8.3.4.4.2.1.4.1 Normal allocation UL MAP Information Element Format
8.3.4.4.2.1.4.2 CDMA allocation UL MAP Information Element Format
8.3.4.4.2.2 DIUC Allocation
8.3.4.4.2.3 UIUC Allocation
8.3.4.4.3 Bandwidth Request Using CDMA Codes
8.3.4.4.3.1 CDMA Bandwidth Request mechanism
8.3.4.4.4 OFDMA Based Ranging
8.3.4.4.4.1 Description of OFDMA Based Ranging Mechanism

Sections Updates

The following text is provided as content to the preceded OFDMA TOC.

8.3.4.4.1 OFDMA Basic parameters

This clause defines OFDMA related basic terminology and relevant parameters.

8.3.4.4.1.1 OFDMA Slot Definition

The OFDMA access scheme defines an access scheme of a two dimensional grid that combines time and frequency division access technique.

As defined in section 8.3.6.3.4.1 – OFDMA Symbol Parameters, each OFDMA symbol is segmented into subcarriers, which are grouped into *sub-channels (a* sub-channel does not necessarily contain consequent subcarriers).

The mini-slot duration is 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 unit of granularity and allocation is *OFDMA Slot*.

The OFDMA Slot is a pair {N, m} that represent the combination of mini-slot (as a time reference) and sub-channel number (as a frequency unit)

8.3.4.4.1.2 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 sub-channel (frequency)--mini-slot (time) domain.

0Figure X1 illustrates an allocation pattern instance of a Region:

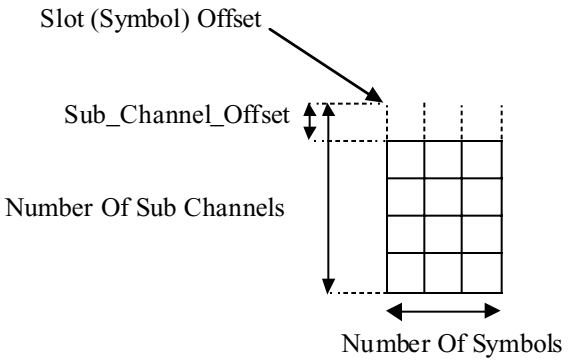

Figure X1: Example of a Two dimensional Pattern

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**.

8.3.4.4.2 OFDMA Frame Structure

In the OFDMA working mode, there are two possibilities to transmit the frame control information (DL MAP or DL+UL MAP messages):

1. The frame control information is transmitted at the beginning of the frame, using all or part of the sub-channels (see 0Figure X2).
2. Taking advantage of the option of forward power control, the transmission of the frame control information is done by using 1-2 sub-channels for the duration of the whole frame while power boosting the used carriers (see Figure X3).

The frame control information is transmitted at the beginning of each frame. The first burst of the frame control information shall always contain the DL-MAP_prefix field of the DL-MAP.

The frame control information can be sent by modulation\coding as defined by the Rate_Id field of the DL-MAP_prefix field of the DL-MAP.

On network entry, the SS upon achieving PHY synchronization, shall demodulate the first burst of the frame trying all the options according to table 1, the SS shall validate the correctness of the demodulating parameters by comparing the used parameters with the Rate_Id value of the MAP_DL_prefix. The validation of the MAP_DL_prefix field is done by the Prefix_CS field.

Table Y1. Rate_Id encoding values

Rate_ID	Modulation	Coding Rate
0	QPSK	1/2
1	QPSK	3/4
2	16QAM	1/2
3	16QAM	3/4
4	64QAM	2/3
5	64QAM	3/4

The Combination of the fields *No_OFDMA_Symbols* and *No_Sub_Channels* defines the structure of the MAP message and position (relative to the top left entry of the DL frame).

0 and 0 describes the downlink OFDMA frame structure with the two options of sending frame control information.

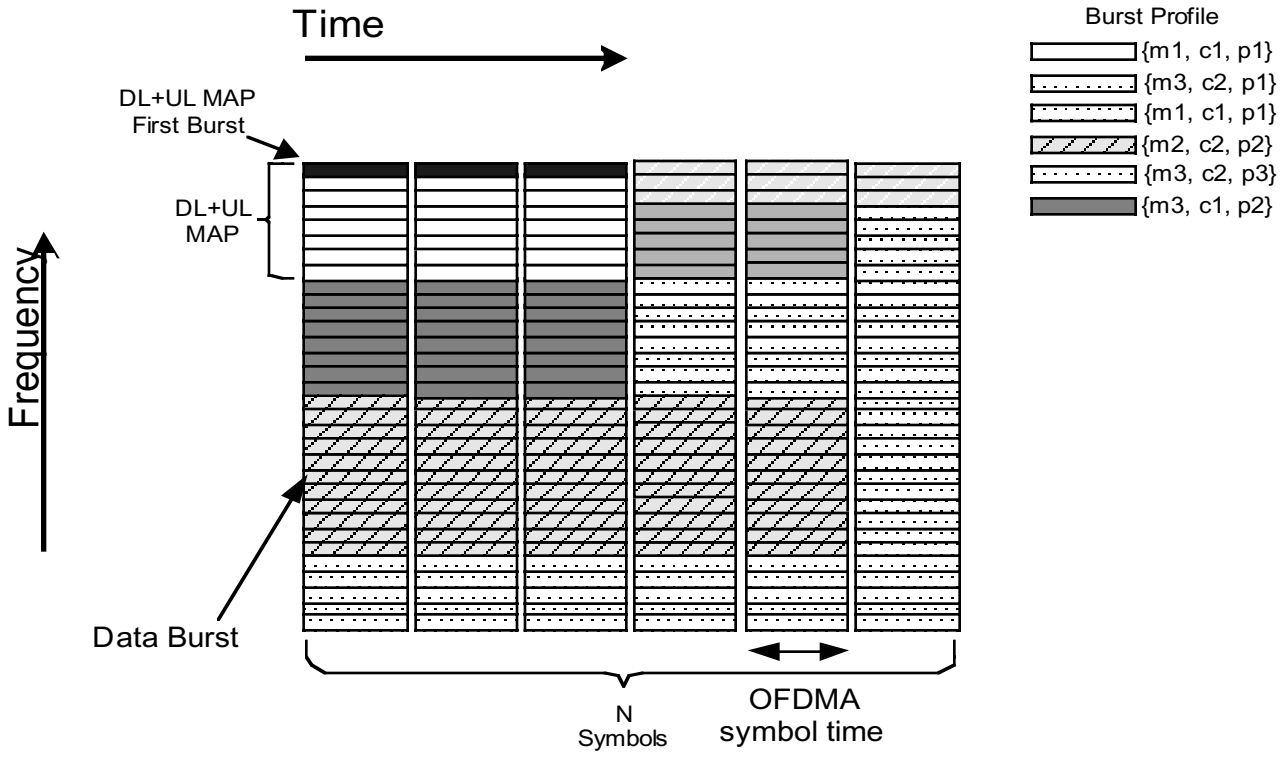

Figure X2: DL Period example #1

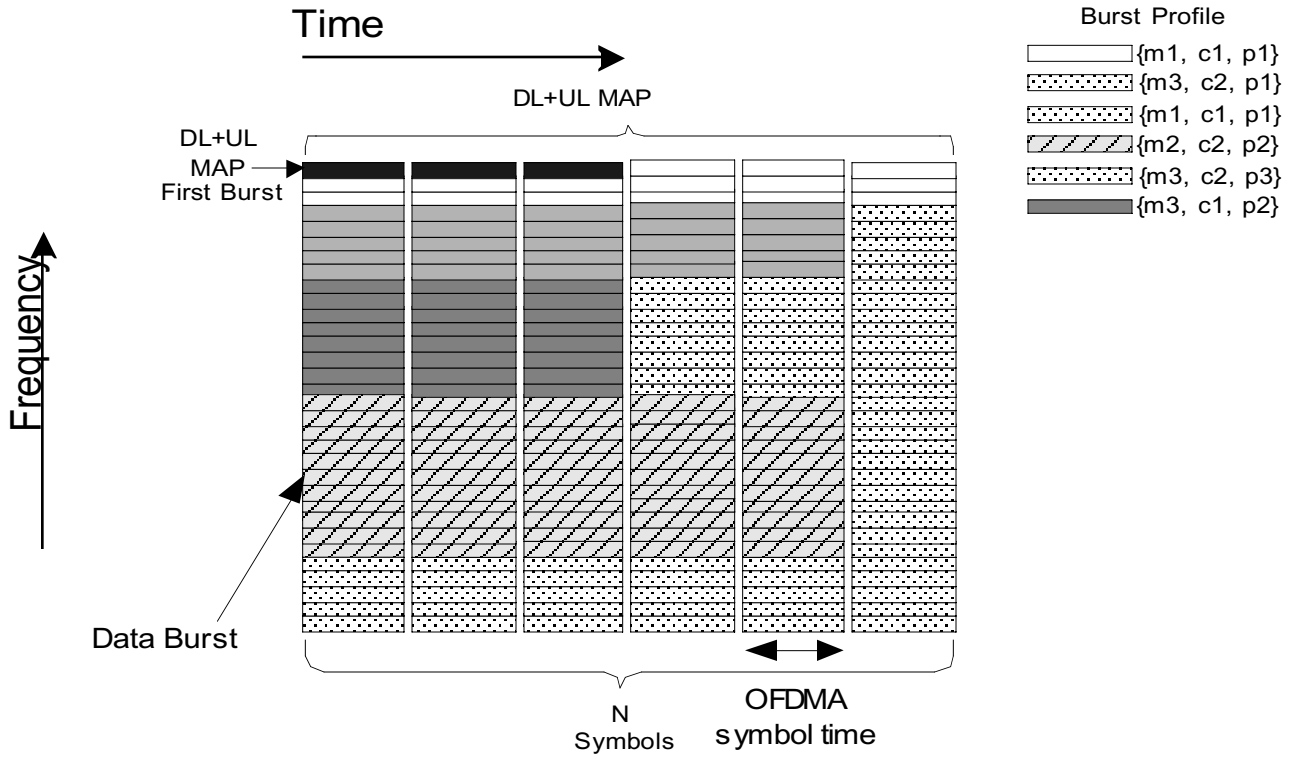

Figure X3: DL Period example #2

8.3.4.4.2.1 MAP Messages

8.3.4.4.2.1.1 OFDMA Downlink MAP message

The Downlink Map (DL-MAP) message defines the access to the downlink information. If the length of the DL-MAP message is a non-integral number of bytes, the LEN field in the MAC header is rounded up to the next integral number of bytes. The message must be padded to match this length but the SS must disregard the 4 pad bits. A BS shall generate DL-MAP messages in the format shown in Table 2.

Table Y2:DL-MAP message format

Syntax	Size	Notes
DL-MAP_Message_Format() {		
Management Message Type	8 bits	= 2
DL_MAP prefix() {		
Rate_ID	8 bits	
DL_MAP_Message_Rectangle() {		Defines the rectangle in the (time, sub-channels) grid used to carry the DL-MAP message. The message always starts at symbol 0 and sub-channel 0
No_OFDMA_Symbols	10 bits	
No_Sub_Channels	6 bits	
}		

Prefix_CS	8 bits	Checksum of the DL-MAP prefix
}		
PHY Synchronization Field() {		
Frame Duration Code	8 bits	
Frame Number	24 bits	
}		
DCD Count	8 bits	
Base Station ID	48 bits	
Allocation Start Time	16 bits	
Number of DL-MAP Elements *n*	16 bits	
for (*i* =1; *i* <*n* ; *i* ++) {		
DL_MAP_Information_Element() {		Each information element defines a rectangle in the (time, sub-channels) grid used to carry a specific burst
}		
if !(byte boundary) {		
Padding Nibble	4 bits	Padding to reach byte boundary
}		

Rate_ID
Enumerated field that describes the modulation/coding of the DL-MAP message. Encoding values of the Rate_ID field are defined in Table 1.

No_OFDMA_Symbols
Indicates the number of OFDMA symbols for the DL_MAP message starting from first symbol of the frame.

No_Sub_Channels
Indicates the number of sub_channels for the DL_MAP message starting from sub_channel 0.

Prefix CS
An 8-bit checksum for the DL-MAP prefix fields, with the generator polynomial g(D)=D^8+D^2+D+1

Frame Duration Code
Indicates the frame duration as per table 156.

Frame Number
A free-running MAC frame number. The Frame Number is incremented by one on each frame and wraps to zero when maximum value is reached.

DCD Count
Matches the value of the Configuration Change Count of the DCD, which describes the burst parameters that apply to this map.

Base Station ID
The Base Station ID is a 48 bit long field identifying the BS. The Base Station ID shall be programmable. The most significant 24 bits shall be used as the operator unique ID.

Allocation Start Time

The Allocation Start Time is the effective start time of the downlink allocation defined by the DL-MAP in units of OFDMA symbols. The start time is relative to the start of the frame in which the DL-MAP message is transmitted.

Number Of Elements
The number of DL information Elements that follows.

8.3.4.4.2.1.2 DL MAP Information Element Format

The OFDMA DL-MAP Information Element defines a two-dimensional allocation pattern as defined in the following table:

Table Y3: DL-MAP IE format

Syntax	Size	Notes
DL_MAP_Information_Element() {		
DIUC	4 bits	
OFDMA Symbol offset	10 bits	
Sub-channel offset	6 bits	
Number of OFDMA Symbols	10 bits	
Number of sub-channels	6 bits	
}		

DIUC
Downlink interval usage code used for the burst.

OFDMA Symbol offset
The offset of the OFDMA symbol in which the burst starts, measured from the start of the MAC frame.

Number of OFDMA Symbols
The number of OFDMA symbols that are used (fully or partially) to carry the DL PHY Burst.

Sub-channel offset
The lowest index OFDMA sub-channel used for carrying the burst.

Number of sub-channels
The number OFDMA sub-channels with subsequent indexes, used to carry the burst.

8.3.4.4.2.1.3 OFDMA Uplink MAP message

The Uplink Map (UL-MAP) message allocates access to the uplink channel. If the length of the UL-MAP message is a non-integral number of bytes, the LEN field in the MAC header is rounded up to the next integral number of bytes. The message must be padded to match this length but the SS must disregard the 4 pad bits. The BS shall generate the UL-MAP in the format shown in **Error! Reference source not found.**:

Table Y4: UL-MAP Message Format

Syntax	Size	Notes
UL-MAP_Message_Format() {		
Management Message Type	8 bits	= 3
Uplink Channel ID	8 bits	
UCD Count	8 bits	
Number of UL-MAP Elements *n*	16 bits	
Allocation Start Time	16 bits	
for (*i* =1; *i* <*n* ; *i* ++) {		
UL_MAP_Information_Element()		Each information element defines a rectangle in the (time, sub-channels) grid used to carry a specific burst
}		
if !(byte boundary) {		
Padding_Nibble	4 bits	Padding to reach byte boundary
}		
}		

Uplink Channel ID
The identifier of the uplink channel to which this Message refers.

UCD Count
Matches the value of the Configuration Change Count of the UCD, which describes the burst parameters which apply to this map.

Number of UL-MAP Elements
Number of information elements in the map.

Allocation Start Time
The Allocation Start Time is the effective start time of the uplink allocation defined by the UL-MAP in units of OFDMA symbols. The start time is relative to the start of the frame in which the UL-MAP message is transmitted.

8.3.4.4.2.1.4 UL MAP Information Element Format

8.3.4.4.2.1.4.1 Normal allocation UL MAP Information Element Format

The OFDMA UL-MAP Information Element defines a two-dimensional allocation pattern for the UL bursts. Information elements define uplink bandwidth allocations. Each UL-MAP message shall contain at least one Information Element that marks the end of the last allocated burst. The Information Elements shall be in strict chronological order within the UL-MAP.
The Connection Identifier represents the assignment of the IE to either a unicast, multicast, or broadcast address.

A Uplink Interval Usage Code (UIUC) shall be used to define the type of uplink access and the burst type associated with that access. A Burst Descriptor shall be included in the UCD for each UIUC to be used in the UL-MAP.

The format of the UL-MAP IE is defined in the following table:

Table Y5: UL-MAP IE format

Syntax	Size	Notes
UL_MAP_Information_Element() {		
CID	16 bits	
UIUC	4 bits	
OFDMA Symbol offset	10 bits	
Sub-channel offset	6 bits	
Number of OFDMA Symbols	10 bits	
Number of sub-channels	6 bits	
}		

CID (Connection Identifier)
Represents the assignment of the IE.

UIUC
Uplink interval usage code used for the burst.

OFDMA Symbol offset
The offset of the OFDMA symbol in which the burst starts, the offset value is defined in units of OFDMA symbols and is relevant to the Allocation Start Time field given in the UL-MAP message.

Number of OFDMA Symbols
The number of OFDMA symbols that are used to carry the UL Burst.

Sub-channel offset
The lowest index OFDMA sub-channel used for carrying the burst.

Number of sub-channels
The number OFDMA sub-channels with subsequent indexes, used to carry the burst.

The end of the last allocated burst is indicated by allocating a NULL burst (CID =0 and UIUC =10) with zero duration. The time instants indicated by the offsets are the transmission times of the first symbol of the burst including preamble.

8.3.4.4.2.1.4.2 CDMA allocation UL MAP Information Element Format

The following Table defines MAP IE for allocation BW for a user that requested bandwidth using Request Code.

This uplink MAP IE is identified by UIUC = 14.

Table Y6: UL-MAP IE format

Syntax	Size	Notes
CDMA_UL_MAP_Information_Element() {		
Ranging Code	6 bits	
Ranging Symbol	12 bits	
UIUC	4 bits	=14
OFDMA Symbol offset	10 bits	
Sub-channel offset	6 bits	
Number of OFDMA Symbols	10 bits	
Number of sub-channels	6 bits	
Ranging Sub Channel	6 bits	
}		

Ranging Code
Indicating the CDMA Code sent by the SS.

Ranging Symbol

Indicating the OFDMA symbol used by the SS.

UIUC
Uplink interval usage code used for the burst.

OFDMA Symbol offset
The offset of the OFDMA symbol in which the burst starts, the offset value is defined in units of OFDMA symbols and is relevant to the Allocation Start Time field given in the UL-MAP message.

Number of OFDMA Symbols
The number of OFDMA symbols that are used to carry the UL Burst.

Sub-channel offset
The lowest index OFDMA sub-channel used for carrying the burst.

Number of sub-channels
The number OFDMA sub-channels with subsequent indexes, used to carry the burst.

Ranging sub-channel
Identifies the Ranging sub-channel used by the SS to send the CDMA code.

The end of the last allocated burst is indicated by allocating a NULL burst (CID =0 and UIUC =10) with zero duration. The time instants indicated by the offsets are the transmission times of the first symbol of the burst including preamble.

8.3.4.4.2.2 DIUC Allocation

The following table defines the UIUC encoding that should be used in the UL-MAP IEs.

Table Y6: UIUC Values

DIUC	Usage
0-12	Different Burst profiles
13	Gap
14	End of MAP
15	Extended

8.3.4.4.2.3 UIUC Allocation

The following table defines the UIUC encoding that should be used in the UL-MAP IEs.

Table Y7: UIUC Values

UIUC	Usage
0	Reserved
1-9	Different Burst profiles
10	Null IE
11	Empty
12	ARQ
13	Power Control
14	CDMA Allocation IE
15	Extended

8.3.4.4.3 Bandwidth Request Using CDMA Codes

This section describes a CDMA code based bandwidth reservation mechanism.

8.3.4.4.3.1 CDMA Bandwidth Request mechanism

The PHY section 8.3.6.3.4.3.1 defines a mechanism of allocating several tones of the OFDMA symbol for modulating special PN codes. The allocated sub-channels are grouped to a Ranging Sub-Channel and the modulated codes are referenced as Ranging Codes.

Specifically subset of the ranging codes is defined as bandwidth request codes (Request Codes).

The proposed mechanism defines the usage of the Request Codes by the SS to request fast bandwidth allocation on a bursty and contentious basis.

Figure X4 describe the messages sequence for CDMA bandwidth request:

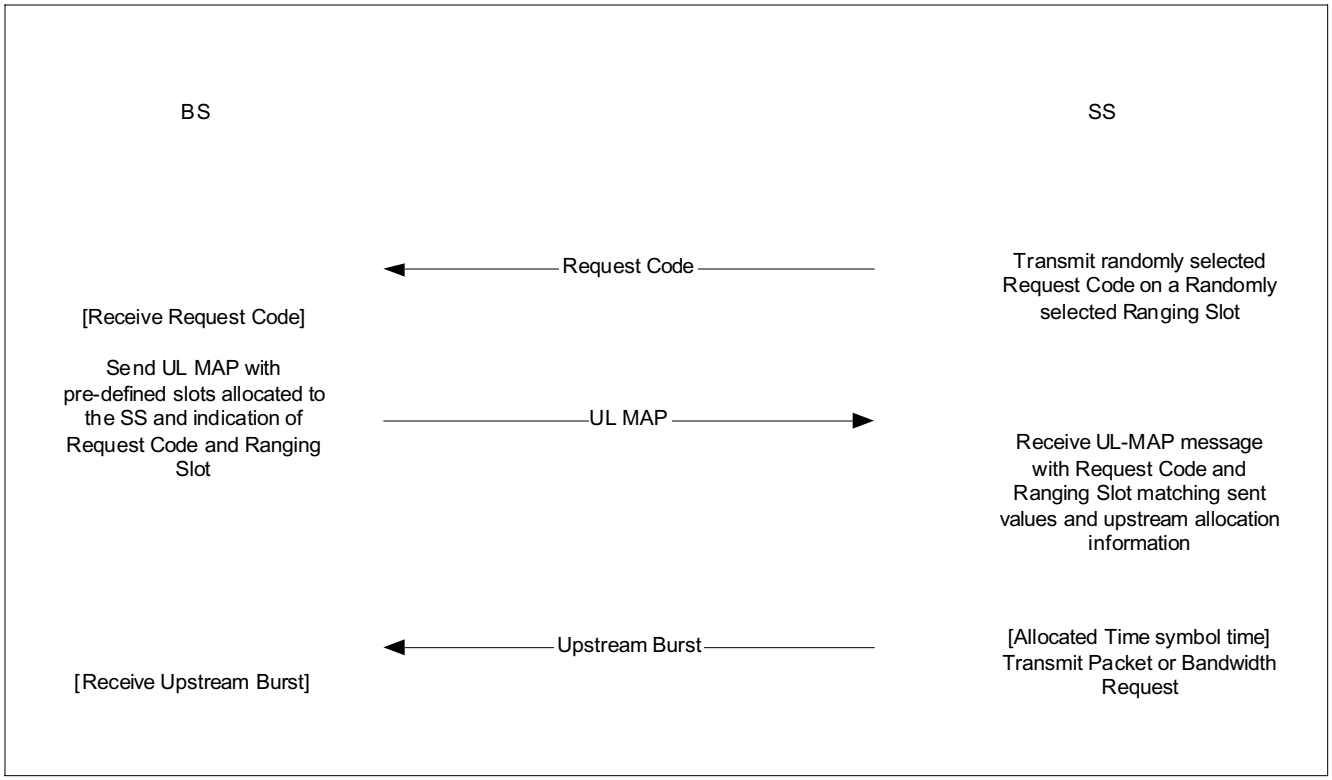

Figure X4: Bandwidth Request in high FFT modes

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 packet or bandwidth request.

In the case of small FFT size, the UL MAP message shall have indication of the synchronization interval size and time (full OFDMA symbols carrying only CDMA codes with one or two sub-channels), the SS shall send the request codes in this interval.

Figure X5 describes the messages sequence for this case:

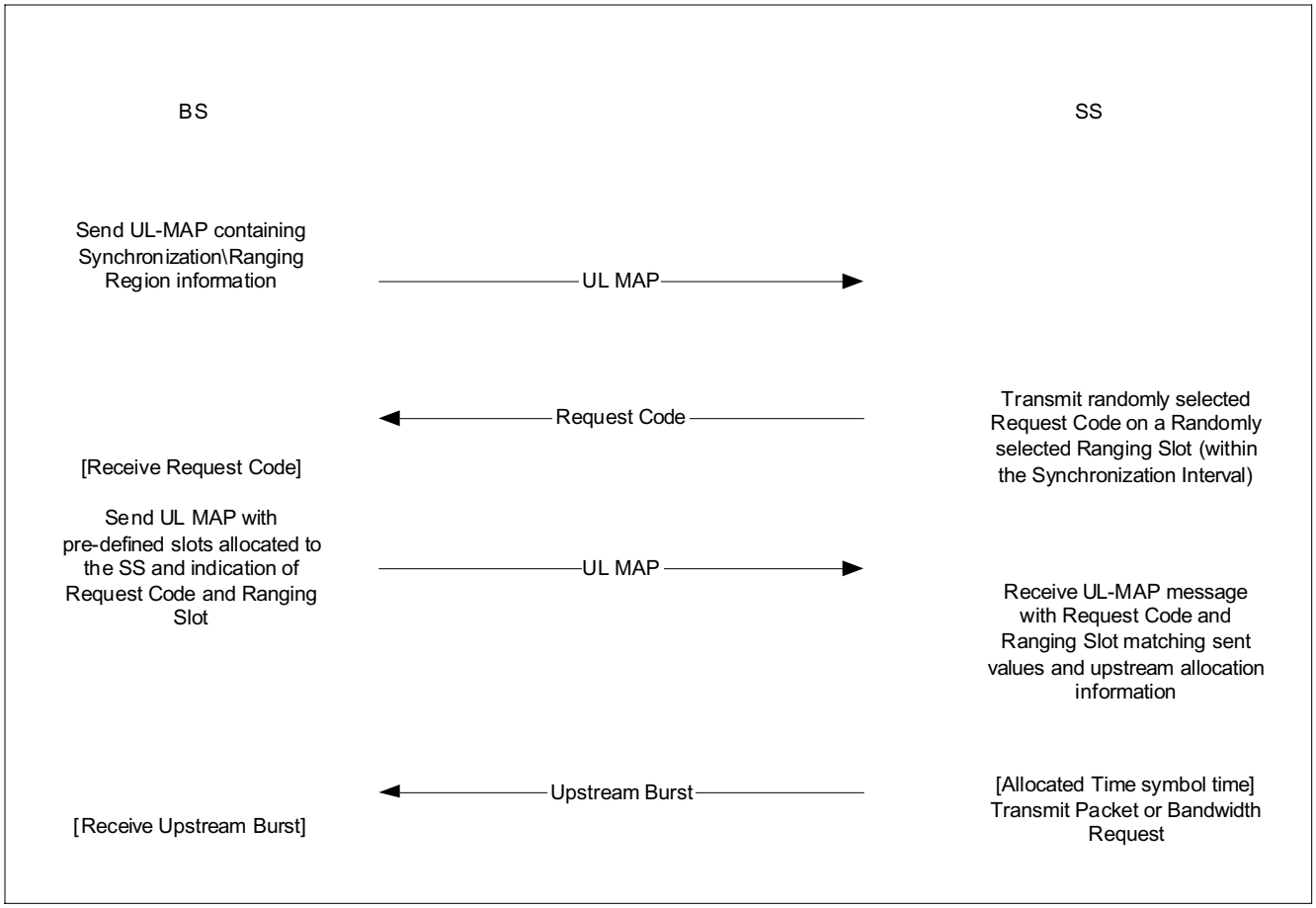

Figure X5: Bandwidth Request in small FFT modes

8.3.4.4.4 OFDMA Based Ranging

The PHY section 8.3.6.3.4.3.1 defines a mechanism of allocating several tones of the OFDMA symbol for modulating special PN codes. The allocated sub-channels are grouped to a Ranging Sub-Channel and the modulated codes are referenced as Ranging Codes.

This section describes the OFDMA based ranging mechanism using Ranging Codes.

The basic OFDMA allocation unit (e.g. *slot*) is a combination of a time symbol and a sub-channel. The current OFDMA (OFDM) based PHY specification defines several working modes, those modes defines two upstream access schemes:

1. Each OFDMA (OFDM) symbol will carry either data or ranging slots
2. Each OFDMA (OFDM) symbol will carry both data and ranging slots

Figure X6 and Figure X7 illustrates the concept of access scheme 1.

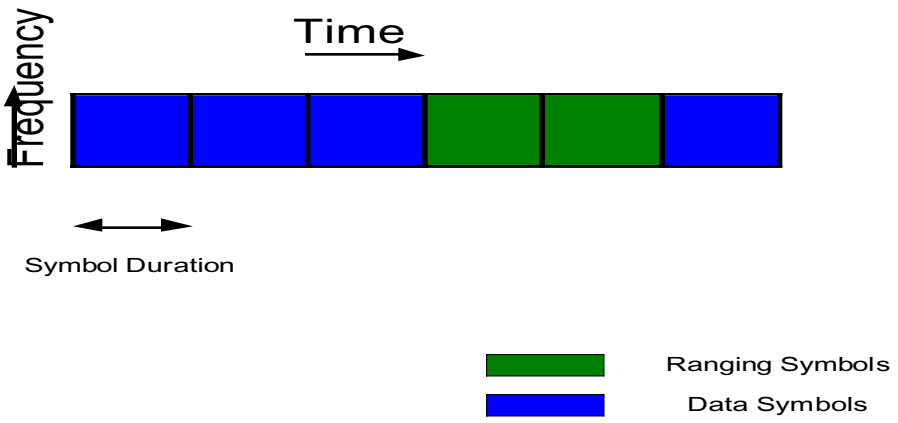

Figure X6: OFDMA Symbols carrying either Ranging or Data slots — General Concept

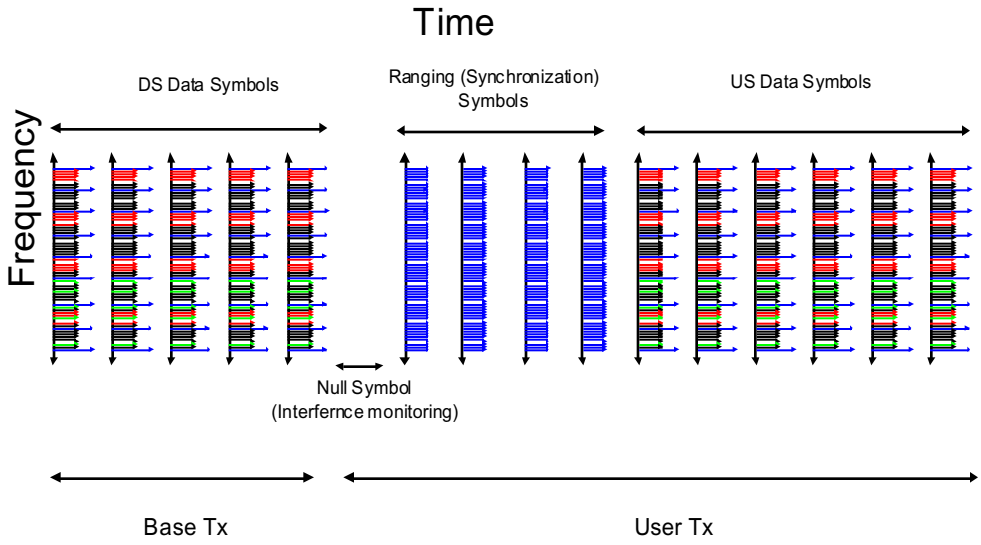

Figure X7: OFDMA Symbols carrying either Ranging or Data slots — In TDD mode

Figure X8 and Figure X9 illustrates the concept of access scheme 2.

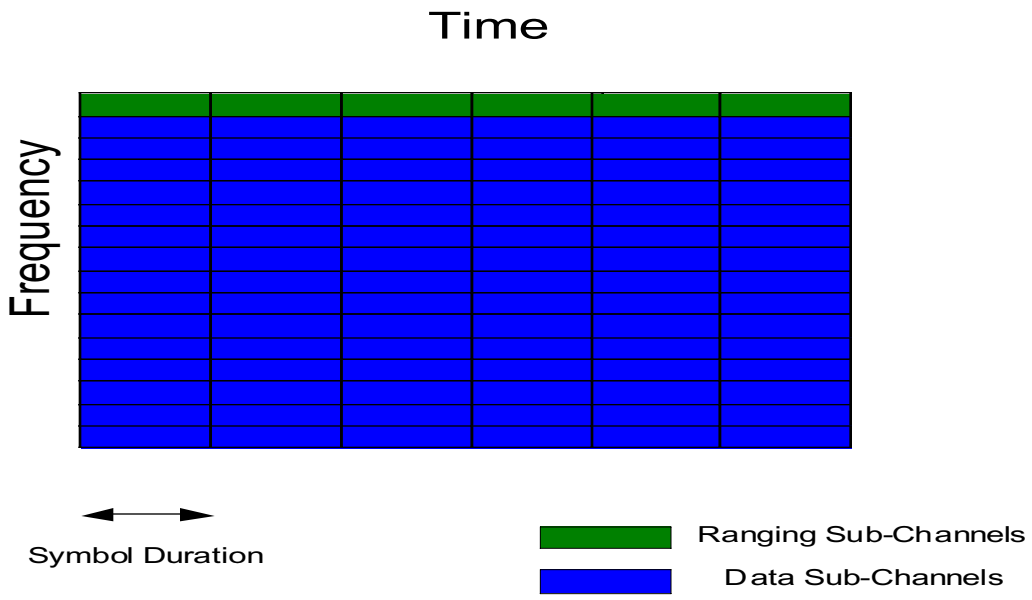

Figure X8: OFDMA Symbols carrying both Ranging and Data slots — General Concept

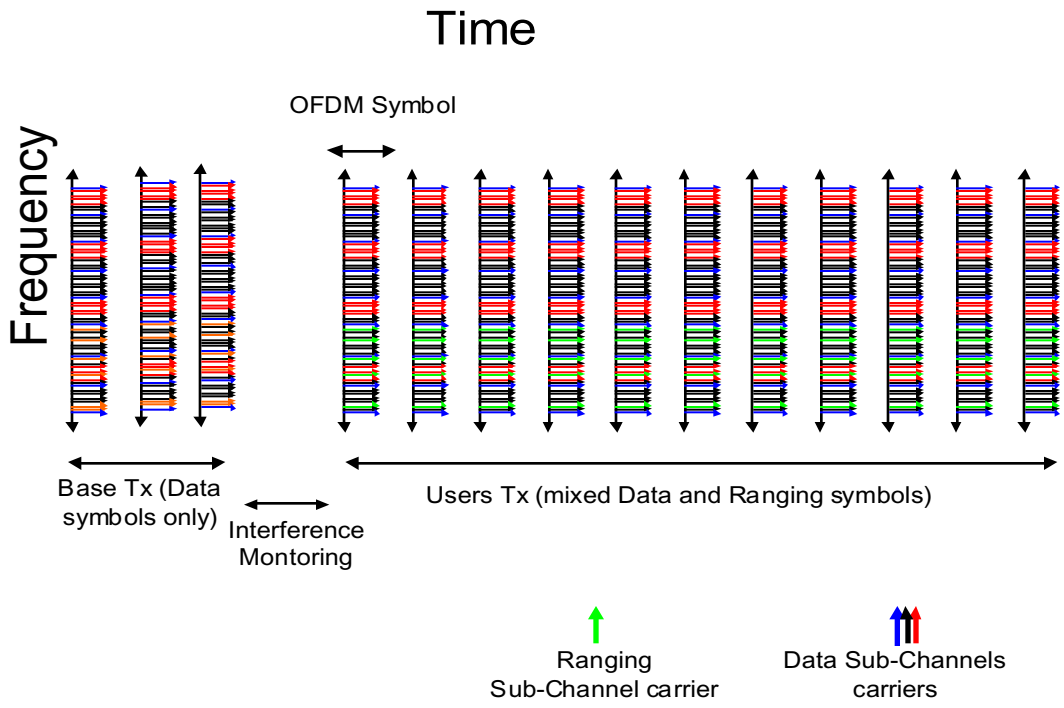

Figure X9: OFDMA Symbols carrying both Ranging and Data slots — In TDD mode

On network entry or at maintenance period, the SS that whishes to perform ranging have to select randomly a Ranging Code (Long or Short), which will be transmitted on a Ranging Sub-Channel in a randomly chosen OFDMA symbol.

8.3.4.4.4.1 Description of OFDMA Based Ranging Mechanism

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

The SS, after acquiring downstream synchronization and upstream transmission parameters, shall choose randomly a Ranging Slot (with the 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 following message flow charts (Figure X10 and Figure X11) describes the ranging adjustments process in the two access modes.

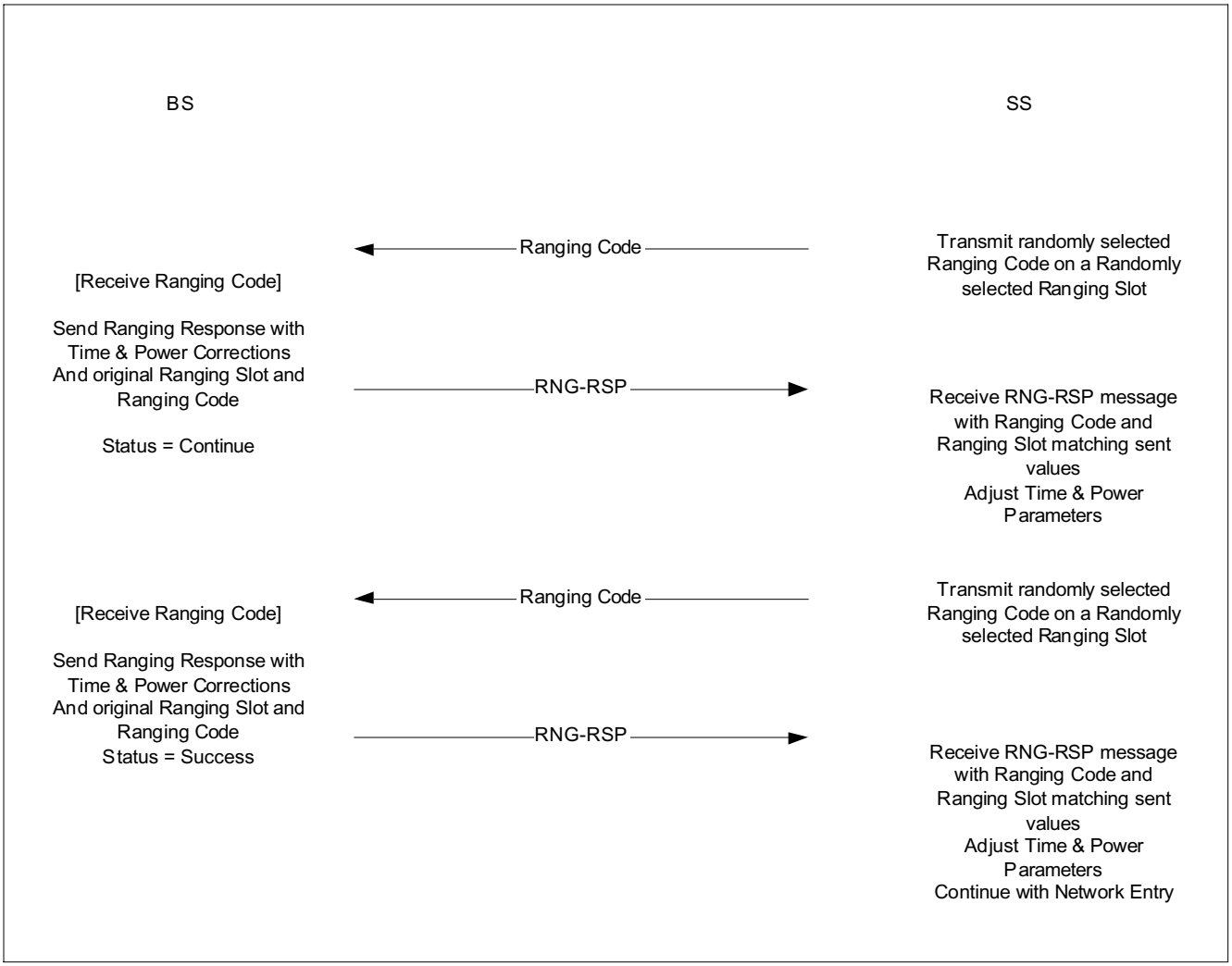
BS
SS
Ranging Code
Transmit randomly selected Ranging Code on a Randomly selected Ranging Slot
[Receive Ranging Code]
Send Ranging Response with Time & Power Corrections And original Ranging Slot and Ranging Code
Status = Continue
RNG-RSP
Receive RNG-RSP message with Ranging Code and Ranging Slot matching sent values
Adjust Time & Power Parameters
Ranging Code
Transmit randomly selected Ranging Code on a Randomly selected Ranging Slot
[Receive Ranging Code]
Send Ranging Response with Time & Power Corrections And original Ranging Slot and Ranging Code
Status = Success
RNG-RSP
Receive RNG-RSP message with Ranging Code and Ranging Slot matching sent values
Adjust Time & Power Parameters
Continue with Network Entry

Figure X10: Ranging and Automatic Adjustments procedure for Access Scheme 2

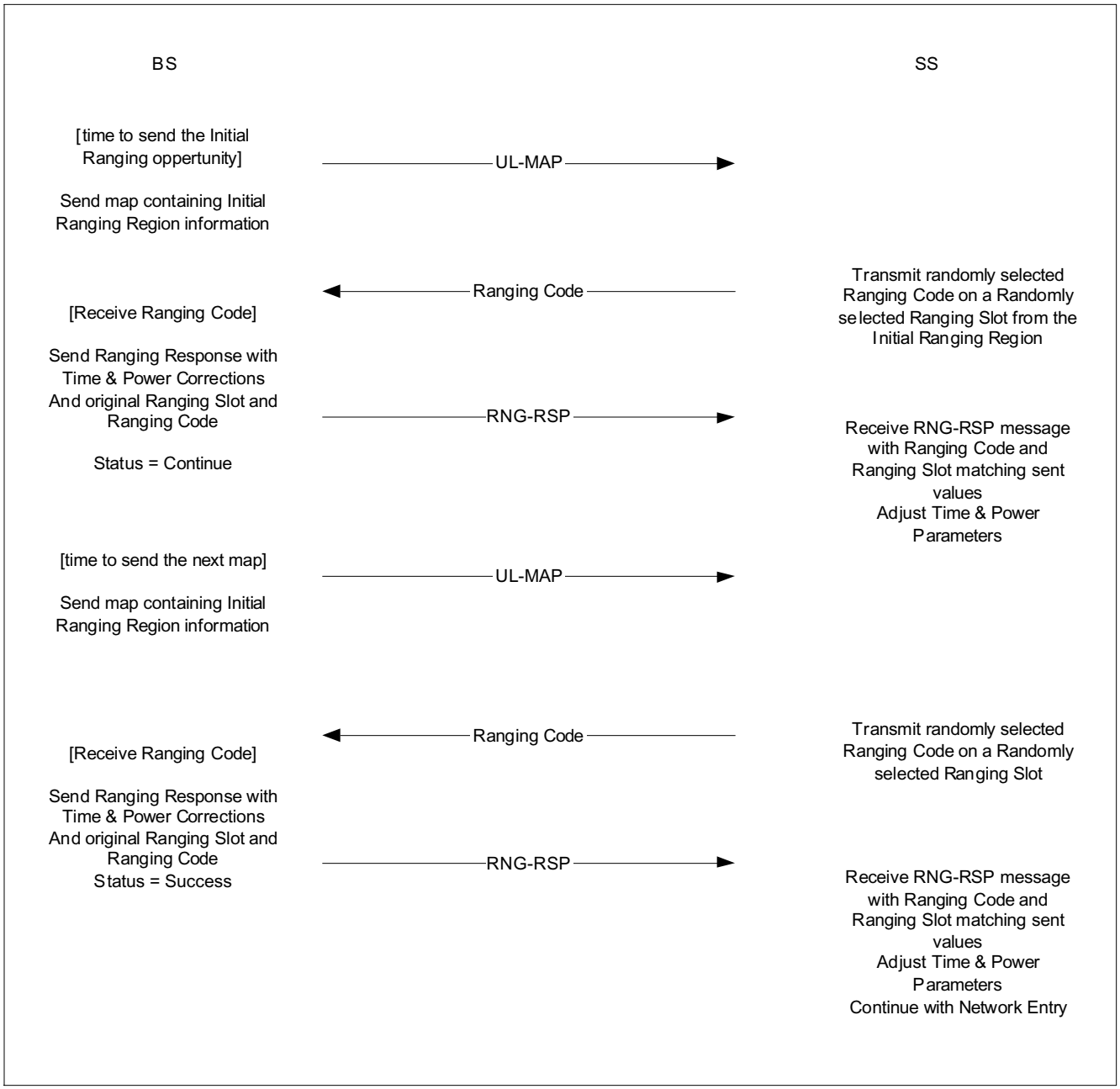

Figure X11: Ranging and Automatic Adjustments procedure for Access Scheme 1

Update Section 6.2.2.3.6

The following addition should be done to the RNG-RSP Message description in section 6.2.2.3.6 line 17 page 82:

Ranging Code:

Indicating the CDMA code sent by the SS.

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 Symbol, Ranging sub-channel and Ranging Code shall be used to address the sending SS.

Ranging Symbol

Indicating the OFDMA symbol used by the SS.

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 Symbol, Ranging sub-channel and Ranging Code shall be used to address the sending SS.

Ranging sub-channel
Identifies the Ranging sub-channel used by the SS to send the CDMA 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 Symbol, Ranging sub-channel and Ranging Code shall be used to address the sending SS.

Update Section 11.1.4

The following TLV values should be added to the RNG-RSP message encoding table, section 11.1.4 page 308:

Table 1: RNG-RSP TLV Addition

Name	**Type** (1 byte)	Length (1 byte)	Value (Variable Length)
Ranging Symbol	12	2	Used to indicate the OFDM time symbol reference that was used to transmit the ranging code (unsigned 12-bit). This TLV is used in conjunction with the Ranging Sub Channel and Ranging Code values to identify the sending SS.
Ranging Sub Channel	13	1	Used to indicate the OFDM sub-channel reference that was used to transmit the ranging code (unsigned 6-bit). This TLV is used in conjunction with the Ranging Sub Channel and Ranging Code values to identify the sending SS.
Ranging Code	14	1	Used to indicate the ranging code that was sent by the SS (unsigned 6-bit). This TLV is used in conjunction with the Ranging Slot value to identify the sending SS.