Project	IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>
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Re:	**IEEE 802.16REVd/D3 Frame Structure for Scalable OFDMA Systems**
Abstract	**A new frame structure is proposed to improve system performance under scalable bandwidth. For scalability, tone spacing and symbol period are fixed and only FFT size vary with system bandwidth. For system performance, the structure supports two new subchannels; band AMC subchannels for system throughput, safety subchannels for users in cell boundary. In addition, dedicated control symbols are introduced for signaling efficiency, the first downlink symbol after preamble is used for carrying system information while the first three uplink symbols are assigned for channel quality report, ranging, and Ack/Nack of downlink data reception. Finally, a new concept of bin and tile are introduced for carrier allocations of AMC subchannels and uplink diversity subchannels, respectively.**
Purpose	**Present how the IEEE802.16d OFDMA frame structure can be enhanced for system performance.**
Notice	
Release	
Patent Policy and Procedures	

A New Frame Structure for Scalable OFDMA Systems

Inseok Hwang, Jaehee Cho, Sanghoon Sung Hun Huh, Soon Young Yoon, Panyuh Joo, Jaeweon Cho

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1. Introduction

Current frame structure in 802.16REVd/D3 2048 FFT OFDMA mode has a limitation to support bandwidth scalability and mobility simultaneously. For example, fixed FFT size cannot provide a unified frame structure since symbol period increases as the bandwidth decreases. In addition, it causes an unacceptable overhead in system with narrow bandwidth such as 1.25 and 2.5 MHz if dedicated symbols for MIMO/AAS preamble, initial random access are introduced. The problem becomes more severe in TDD system when a short frame length required for fast link control. To handle these limitations and improve overall system performance, a new flexible frame structure is proposed. For scalability, tone spacing and symbol period are fixed and only FFT size varies from 2048 to 256 as system bandwidth scales down from 20 MHz to 2.5 MHz. For better system performance, the proposed frame structure supports two new subchannels; band AMC subchannels for system throughput, safety subchannels for users in cell boundary. In addition, dedicated control symbols are introduced for signaling efficiency, the first downlink symbol after preamble is used for carrying system information while the first three uplink symbols are assigned for channel quality report, ranging, and Ack/Nack of downlink data reception. Finally, a new concept of bin and tile are introduced for carrier allocations of AMC subchannels and uplink diversity subchannels, respectively.

2. Design Requirement

Desired properties of frame structure for scalable OFDMA cellular operation can be summarized as follows

1) Fixed tone spacing for unified frame structure
2) Symbol time tradeoff between guard time overhead for delay spread and ICI from Doppler spread
3) Short frame length for fast link control especially for TDD systems
4) Dynamic allocation of diversity channels for mobile users and freq. selective AMC channels for stationary users
5) Dedicated signaling channels for fast adaptive modulation coding and H-ARQ
6) Dedicated uplink time slot for initial random access to reduce interference to traffic channels
7) Safety channels for service quality of users in cell boundary
8) Support frequency reuse of 1 and 3

To satisfy the above requirement, a new frame structure is developed.

3. Proposed Frame Structure

A. System Parameter

To support scalable bandwidth from 2.5 MHz to 20 MHz, the following system parameter was chosen after considering trade-off between guard time overhead and ICI from Doppler spread. The scalability of FFT size with system bandwidth should be kept for a unified frame structure while the exact values of sampling frequency can be changed

Table 1. System Parameter

Parameter	Values			
System BW	2.5 MHz	5 MHz	10 MHz	20 MHz
FFT Size	256	512	1024	2048
Samp. Frequency	2.5 MHz	5 MHz	10 MHz	20 MHz

Tone Spacing	9.975625 kHz			
Total OFDM Symbols	42			
Used Subcarriers	216	432	864	1728
Data Subcarriers	192	384	768	1536
Pilot Subcarriers	24	48	96	192

B. Frame Structure

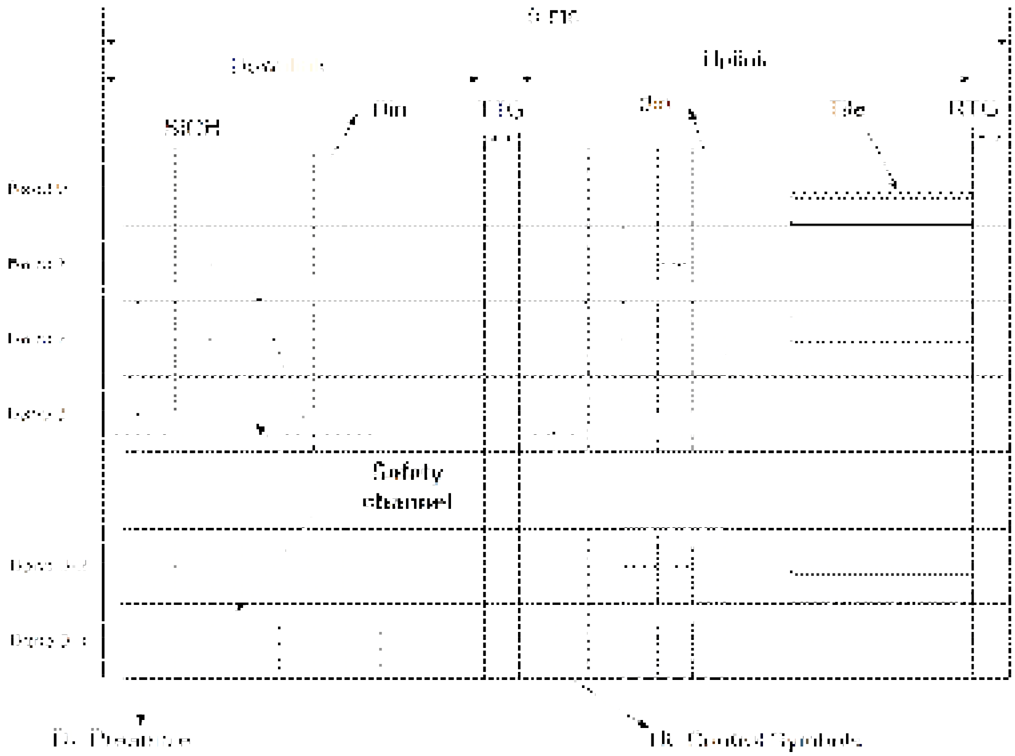


Figure 1 – TDD Frame Structure

For a TDD system, each frame starts with downlink, a BS to SS transmission. The downlink transmission begins with two preambles followed by a SICH symbol as shown in Figure 1. In the uplink, transmission begins with control symbols. In order to allow BS to turn around, TTG and RTG shall be inserted between downlink (DL) and uplink (UL) in the middle of a frame and at the end of a frame, respectively. The number of downlink and uplink symbols can be changed with a granularity of six symbols.

Both in downlink and uplink, there are two kinds of subchannels, diversity subchannels and AMC subchannels. Accordingly, transmission period can be divided into diversity subchannel period and AMC subchannel period. Diversity subchannel consists of 54 distributed tones within multiple symbols in downlink. In uplink, a tile, which is composed of the set of 3 contiguous subcarriers through 6 contiguous symbols, is a basic allocation unit for diversity subchannel. A diversity subchannel is made up of 3 tiles, which are spread over whole frequency band in uplink. A tile structure is shown in Fig. 2. For AMC subchannel, a bin, which is the set of 9 contiguous subcarriers within an OFDMA symbol, is a basic allocation unit both in downlink and uplink. A bin structure is shown in Figure 3. The pilot locations of within bins and tiles can be changed for better filtering gain for channel estimation.

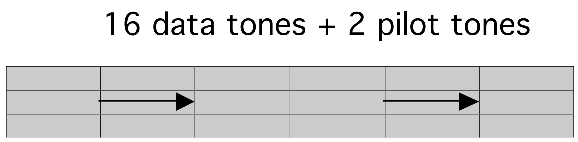


Figure 2 – Bin Structure

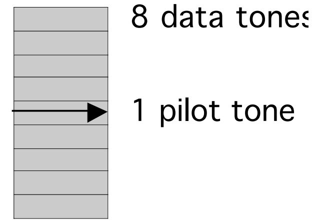


Figure 3 – Bin Structure

A group of 4 rows of bins is called a band. AMC subchannel consists of 6 contiguous bins in a same band. A frame consists of multiple bands. Total number of bins in a whole frequency band depends on bandwidth as shown in Table 4.

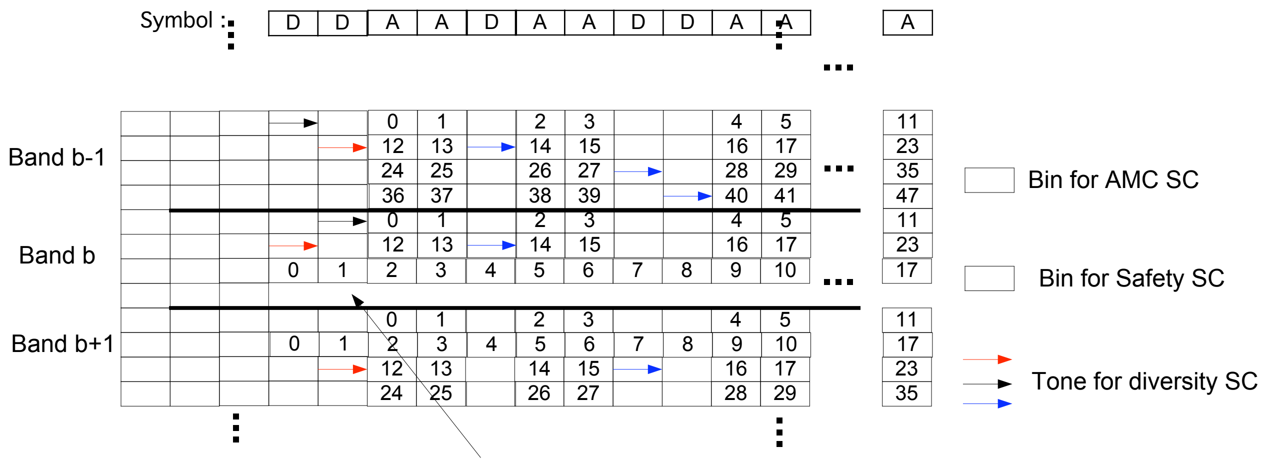
Table 4 – Number of bands and bins

Bandwidth	2.5 MHz	5 MHz	10 MHz	20 MHz
N_{FFT}	256	512	1024	2048
Number of bands	6	12	24	48
Number of bins per bands	4	4	4	4

The downlink symbol right after DL preamble is always used for diversity subchannels and constitutes a SICH (System Information Channel) symbol. Safety channel, which consists of the reserved subcarriers for safety operation, is also to be broadcasted in SICH symbol. In uplink, the first three OFDMA symbols are used for control symbols. Ranging channels, ACK channels, and CQI channels are transmitted through control symbols. For reuse 3 deployment, set of bands with the same index of modulo 3 consists a frequency group.

1) Downlink Frame Structure

Downlink frame structure is shown in Figure 4. Downlink transmission period can be divided into diversity subchannel period and/or AMC subchannel period. Diversity subchannels consists of distributed tones within multiple symbols and AMC subchannel consists of 6 contiguous bins in a same band. The number of diversity symbol (D) and AMC symbol (A) can vary depending on distribution of SS's channel condition. The downlink symbol right after DL preamble is always used for diversity subchannels and constitutes a SICH (System Information Channel) symbol. Safety channel, which consists of the reserved subcarriers for safety operation, is also to be broadcasted in SICH symbol.



Note: Safety channel is each BS's reserved frequency bin not used for the SS of the serving BS. Safety subchanne(SC) is the frequency bin allocated for the SS which is connected to the serving BS and has requested the bin in safety mode. This bin is other BS's safety channel.

Figure 4 – Downlink Frame Structure

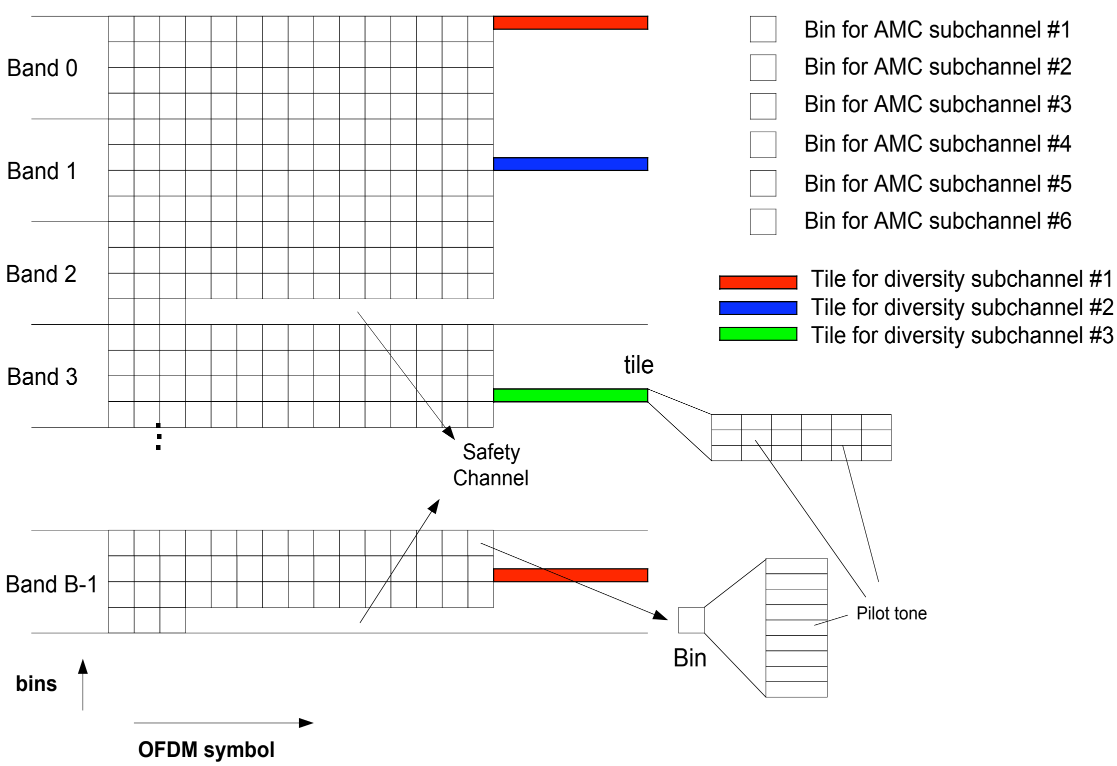


Figure 5. Uplink Frame Structure

2) Uplink Frame Structure

In the uplink, there are two kinds of subchannels, AMC subchannels and diversity subchannels. The first three OFDMA symbols are used for ranging channels, ACK channels, and CQI channels as shown in
5. Basic allocation unit for diversity subchannel is a tile. A diversity subchannel consists of 3 tiles spread over whole frequency band. Basic allocation unit for AMC subchannel is a bin. One AMC subchannel consists of 6 bins. As in downlink, the configuration of AMC and diversity uplink symbols can vary. Since uplink time interval for initial random access are separated from data symbols, interference from SS in initial access to traffic channels can be reduced. In addition, fast downlink link control such as adaptive modulation coding and H-ARQ is enabled through dedicated control channels such as ACK channels, and CQI channels. The H-ARQ is essential for higher system throughput and reliability under imperfect channel quality measurement and packet scheduling delay.

C. Frame Structure for FDD Systems

Downlink and uplink frame structure for FDD mode is shown in Figure 4,
5, respectively. Downlink transmission period can be divided into diversity subchannel period and AMC subchannel period in the same way as in TDD mode. Uplink frame structure in FDD mode is also basically the same as the one in TDD mode.

D. AAS Operation

When operating in the AAS mode, only AMC subchannelization is used for uplink and downlink traffic bursts. Downlink frame structure can be divided into preambles, SICH, MAP bursts, and traffic bursts as shown in Figure 6. The SICH symbol and AAS_MAP_Burst_Location_IE can be transmitted by changing a beam index frame by frame while MAP Bursts #0 ~ #N-1 has the dedicated beam index for coverage extension.

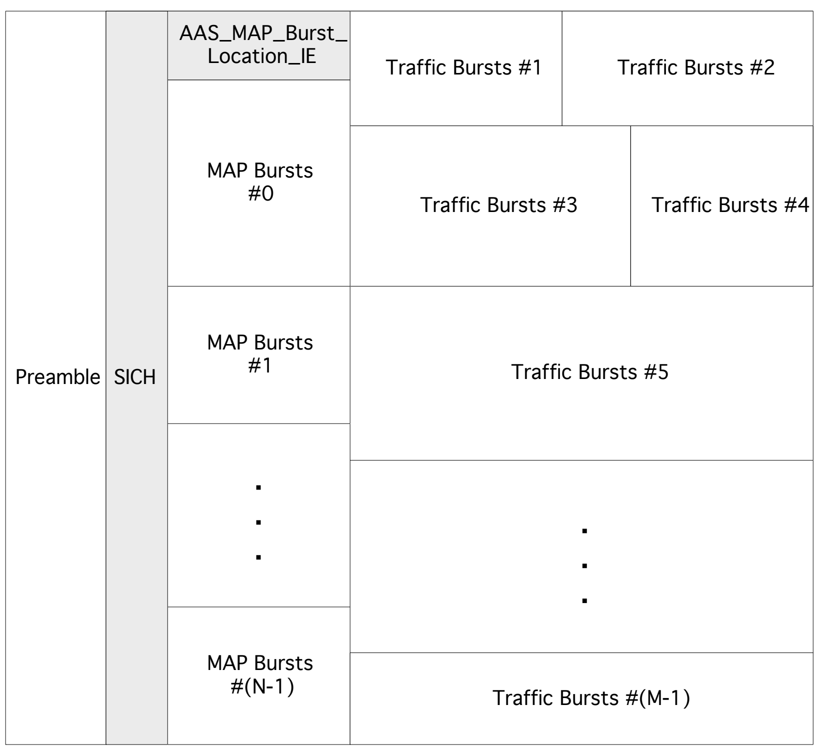


Figure 6 – Downlink Frame Structure for AAS

4. Summary and Conclusion

To achieve bandwidth scalability and better system performance, a unified frame structure was proposed. The proposed structure have flexibility of AMC and diversity channel management for system throughput while safety channel can give better service quality for users in cell boundary. In addition, the proposed structure can support AAS operation. For better signaling efficiency, the first downlink symbol after preamble is used for carrying system information while the first three uplink symbols are assigned for channel quality report, ranging, and Ack/Nack of downlink data reception. Finally, a new concept of bin and tile are introduced for carrier allocations of AMC subchannels and uplink diversity subchannels, respectively.

Proposed Text Changes

[Replace IEEE P802.16-REVd/D3-2004 "8.4.4 Frame structure" with the following text.]

8.4.3 Frame structure

8.4.3.1 Frame structure

For a TDD system, each frame starts with downlink, a BS to SS transmission. The downlink transmission begins with two preambles followed by a SICH as shown in Figure 1. In the uplink, transmission begins with a control symbols. In order to allow BS to turn around, TTG and RTG shall be inserted between downlink (DL) and uplink (UL) in the middle of a frame and at the end of a frame, respectively.

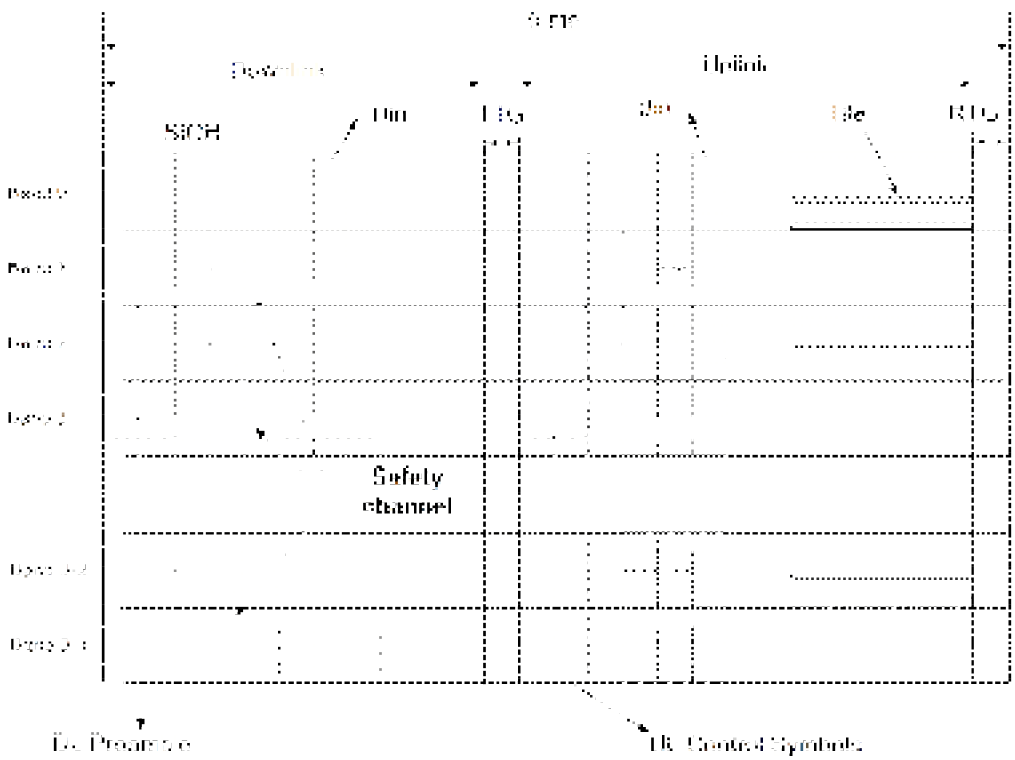
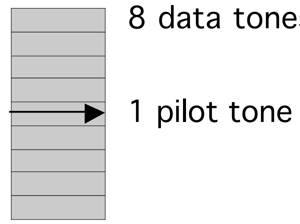


Figure 1 – Frame structure

Both in downlink and uplink, there are two kinds of subchannels, diversity subchannels and AMC subchannels. Accordingly, transmission period can be divided into diversity subchannel period and AMC subchannel period.

Diversity subchannel consists of 54 distributed tones within multiple symbols in downlink. In uplink, a tile, which is composed of the set of 3 contiguous subcarriers through 6 contiguous symbols, is a basic allocation unit for diversity subchannel. A diversity subchannel is made up of 3 tiles, which are spread over whole frequency band in



uplink. A tile structure is shown in

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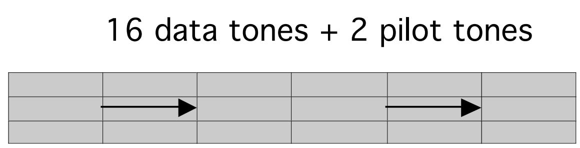

Figure 2 – Tile structure

For AMC subchannel, a bin, which is the set of 9 contiguous subcarriers within an OFDMA symbol, is a basic allocation unit both in downlink and uplink. A bin structure is shown in Figure .

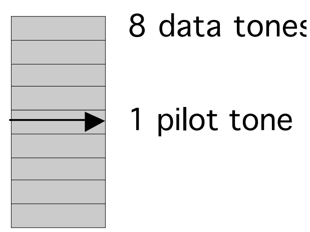

Figure 3 – Bin structure

A group of 4 rows of bins is called a band. AMC subchannel consists of 6 contiguous bins in a same band.

A frame consists of multiple bands. Total number of bins in a whole frequency band depends on bandwidth as shown in Table .

Table 1 – Number of bands and bins

Bandwidth	2.5MHz	5MHz	10MHz	20MHz
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The downlink symbol right after DL preamble is always used for diversity subchannels and constitutes a SICH (System Information Channel) symbol. Safety channel, which consists of the reserved subcarriers for safety operation, is also to be broadcasted in SICH symbol.

In uplink, the first three OFDMA symbols are used for control symbols. Ranging channels, ACK channels, and CQI channels are transmitted through control symbols.

8.4.3.2 FDD Frame structure

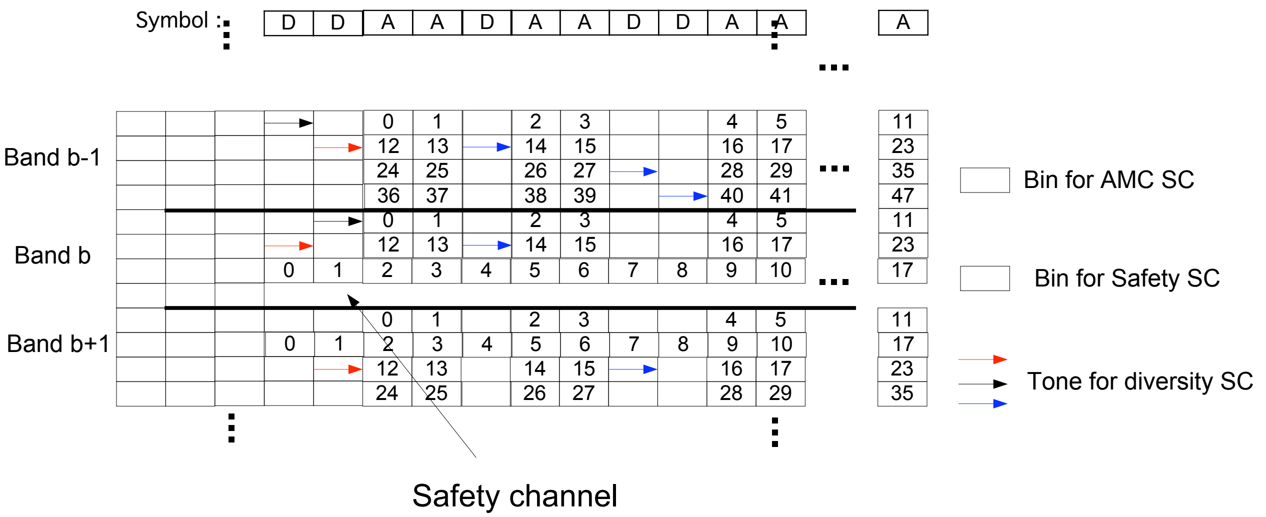
8.4.3.2.1 Downlink frame structure

Downlink frame structure for FDD mode is shown in Figure . Downlink transmission period can be divided into diversity subchannel period and AMC subchannel period in the same way as in TDD mode.

8.4.3.2.2 Uplink frame structure

Uplink frame structure for FDD mode is shown in

. Uplink frame structure in FDD mode is basically the same as the one in TDD mode.



Note :

Safety channel is each BS's reserved frequency band which is not used for the BS's SS. Safety subchannel(SC) is the frequency band allocated for the BS's SS which has requested the band in safety mode. This band is other BS's safety channel.

Figure 4 – Downlink frame structure

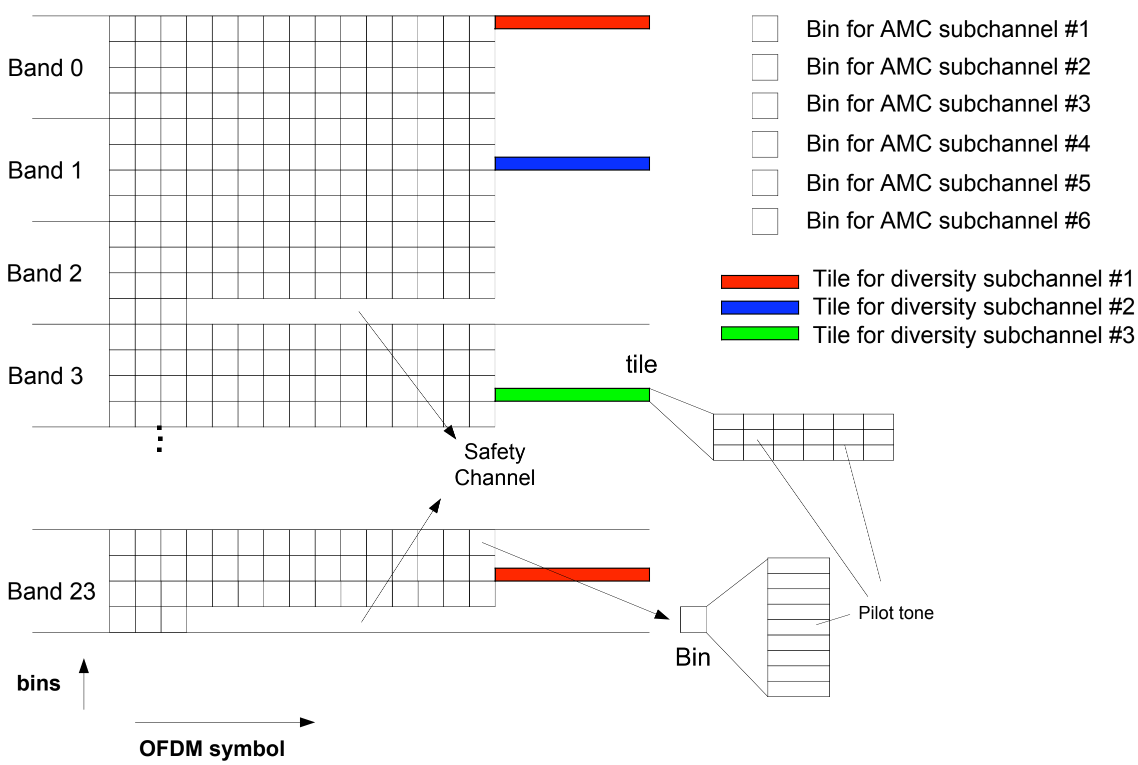


Figure 5 – Uplink frame structure

8.4.3.3 AAS operation

When operating in the AAS mode, only AMC subchannelization is used for uplink and downlink traffic bursts. Downlink frame structure can be divided into preambles, SICH, MAP bursts, and traffic bursts as shown in Figure .

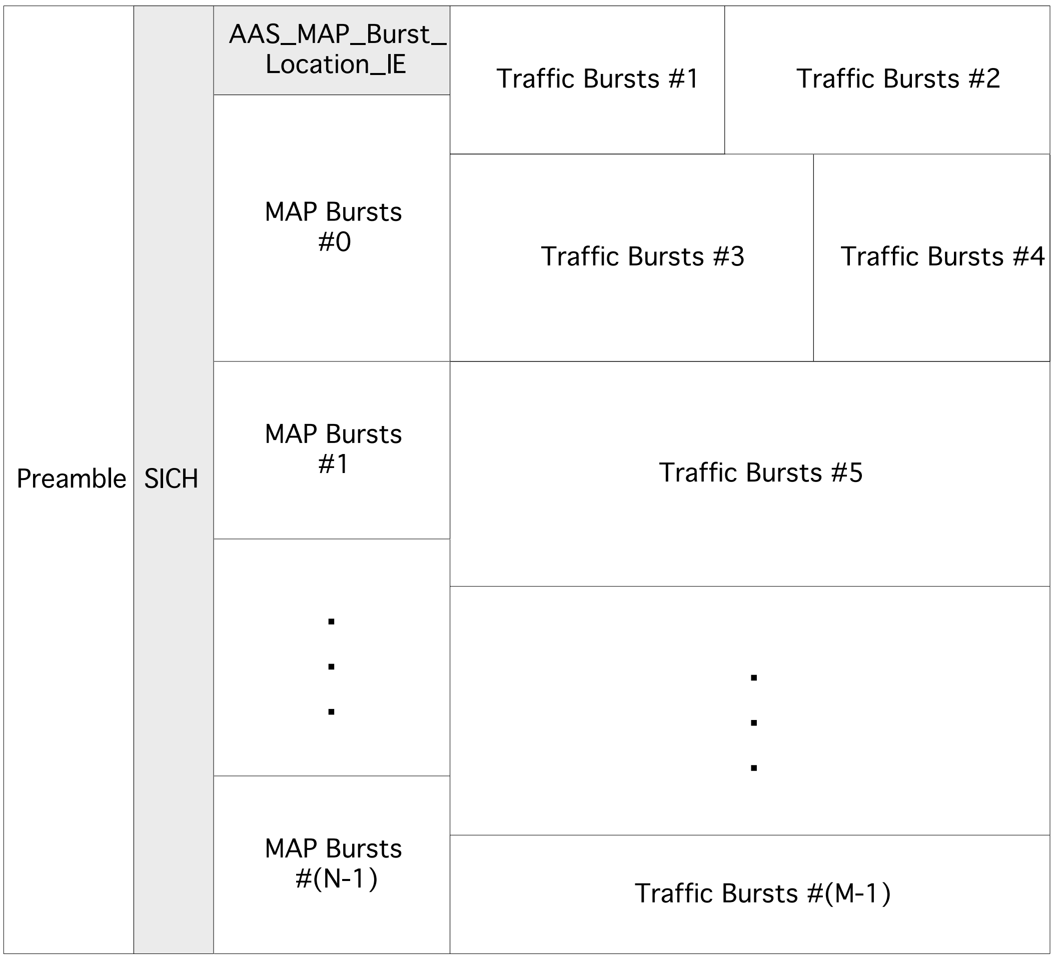


Figure 6 – Downlink frame structure for AAS

8.4.3.3.1 Preambles

First two OFDMA symbols are used as preambles, as described in **Error! Reference source not found.**. Preambles are transmitted through broad beamforming pattern in the same way as in non-AAS mode. It is used for network synchronization and cell identification.

8.4.3.3.2 SICH

System information channel is assigned in a separated OFDMA symbol following preambles. SICH is transmitted by BS with the AAS beam in a specific direction in a given time.

8.4.3.3.3 AAS_MAP_Burst_Location IE

Subchannel 0 of the DL frame is used for delivering MAP allocation information. AAS_MAP_Burst_Location_IE() is transmitted in the same beamforming pattern as SICH. Position of starting subchannels for each MAP burst are indicated in AAS_MAP_Burst_Location _IE().

Physical structure for the AAS_MAP_Burst_Location_IE () is shown in Figure 7. The AAS_MAP_Burst_Location_IE () is transmitted with QPSK rate 1/12.

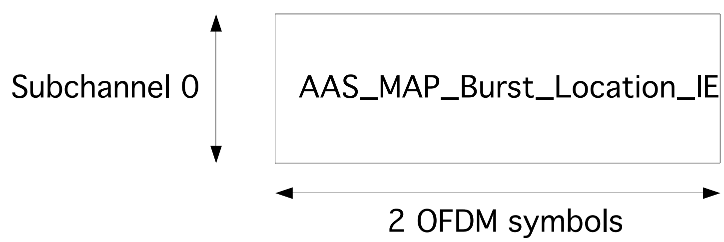


Figure 7 – Example of allocation for AAS_MAP_Burst_Location IE

The contents of the AAS_MAP_Burst_Location_IE () payload is described by Table 2.

Table 2 – AAS_MAP_Burst_Location_IE format

Syntax	Size	Notes
AAS_MAP_Burst_Location _IE {		
No. symbol for AAS_MAP	1 bits	0 : 2 OFDMA symbols 1 : 3 OFDMA symbols
Subchannel_offset	7 bits	
No. subchannels	4 bits	

8.4.3.3.4 Broadcasting MAP bursts

Each MAP burst is dedicated at the direction of the BS for active AAS scanning. These bursts are used to transmit AAS_DL_Scan_IE() as shown in Table 3. The AAS_DL_Scan_IE() will be transmitted with QPSK rate 1/12.

Table 3 – AAS_DL_Scan_IE format

Syntax	Size	Notes
AAS_DL_Scan_IE {		
AAS_Ranging_Allocation_IE() {		
Subchannel offset	7 bits	
No. subchannels	2 bits	
}		
AAS_MAP_Allocation_IE() {		
For (n=0; n<N_user; n++) {		
TID	10 bits	
Band ID	6 bits	
Nep	6 bits	
No. Subchannels	4 bits	
}		
}		