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Re:	Call for contributions IEEE 802.16e-02/01: Mobility Enhancements to the IEEE Standard 802.16/802.16/a/c
Abstract	Proposal for mobility enhancements to 802.16a
Purpose	To be used as a starting point for enchanced functionality that allows mobility with the 802.16a system.
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OFDMA-256 Mode for 802.16e

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1. Introduction

The following is a response to the call for contributions for the IEEE 802.16 Task Group E [1]. In this document, we outline enhancements to the 802.16a standard that will support mobility and, as dictated by the call for contributions, fully support the 802.16a air interface.

2. System Considerations

2.1 Full Support of the 802.16a Air Interface

One of the primary criteria for the 802.16e system is "Full support of the IEEE 802.16a air interface. Because of this, it is critical that no significant changes be made to the 802.16a system in order to support an 802.16e client. Also, it must be shown that 802.16e devices will work in an 802.16a environment, and 802.16a devices will work in an 802.16e environment. A key consideration is network entry. Not only should an 802.16e device be able to enter an 802.16a network, its presence should also not cause a reduction in availablity or throughput for the existing 802.16a clients.

2.2 Support for Vehicular Terminals and Battery Operated Devices

Vehicular terminals will most often be some sort of battery operated device with a low gain antenna. For this reason, power related factors (power requirements, coverage) must be considered. It is even fair to say that lower throughput can be used as an acceptable “trade” for higher coverage or lower battery drain. However, there are limits to this “trade”, and schemes that provide more gain in exchange for ridiculously low throughput are not acceptable.

2.3 Support for Outdoor-to-Indoor Penetration

Outdoor-to-indoor penetration is an unnecessary requirement that will result in throughput levels far below the levels targeted by 802.16a systems. The uplink throughput of user devices with sufficient power concentration to enable outdoor-to-indoor applications will be degraded proportionally to the number of subchannels required to achieve the required power concentration. For the outdoor-to-indoor scenario, we believe that 802.16a/e should focus on providing high bandwith access to indoor hot spots.

2.4 Power Control for Vehicular Operation

As a vehicle proceeds through a cell, its required power output level will move through a considerable range. We suggest a combination of adjustable coding rates, adjustable transmit power levels, and adjustable subchannelization schemes is appropriate to provide the range of power needed to maintain a link. For example, a device at the fringe of the cell might enter the network using subchannelization, but as that device moves closer to the AP, it may be able to handle a full channel and lower FEC coding rate. These parameters should be adjusted thoughout the duration of the link, and these adjustments should be automatic.

3. Increased Coverage using Subchannelization

3.1 Power Requirements

Currently, the 802.16a subchannelization scheme allows for up to four (4) subchannels. One of those subchannels is able to boost its transmit power by 6 dB. With the introduction of an eight (8) subchannel scheme, that power boost can be increased to 9 dB, while maintaining an adequate maximum burst rate. This is an acceptable trade-off between throughput and increased link budget.

3.2 Preamble Sensitivity

In keeping with the requirement that the system be compatible with 802.16a, we propose that the same synchronization preambles be used. Since the current preamble is sensitive enough to synchronize well below 10 dB lower than the usable data SNR, no changes are required to ensure compatiblilty between 802.16a and 802.16e systems. However, increasing the number of subchannels beyond 8 results in a system whose data is transmitted at a power level that exceeds the sensitivity of the current preamble scheme. In other words, without (incompatible) changes to the preamble, the system would not be able to synchronize at the levels the highly subchannelized data offers.

3.3 Higher Levels of Subchannelization

There is a trend toward very high subchannelization. But using more than eight (8) subchannels presents many problems:

- Not enough pilot symbols in the current system. As a result, complex schemes involving pseudorandom pilot locations are required.

- The current preamble cannot be used for network entry. The sensitivity of the preamble is too low to work correctly in the fringe conditions enabled by high subchannelization schemes. Changing the synchronization preamble means full support for 802.16a is not met.

- Network entry also means transmitting MAC layer information. Currently, 24 bytes of data are required, and as the number of subchannels increases, very long network entry packets are required. This quickly becomes impractical in the mobile environment.

3.3.1 Link Budget Improvements vs. FEC Performance Hits

There is a crossover point at which the gain in power concentration is offset by a reduction in FEC performance. We don't believe that the theoretical gains of an excessive amount of sub-channels will actually be seen. Here again we believe that 8 subchannels with a theoretical gain of 9 dB is a good trade off.

3.4 Scheme for Eight Subchannels

3.4.1 Subchannel Mapping

The subchannel mapping is shown below. The new scheme is a further subset of the existing 802.16a subchannelisation and is fully backwards compatible.

	-100..	-88..	-75..	-63..	-50..	-38..	-25..	-13..	1..	14..	26..	39..	51..	64..	76..	89..
	-89	-76	-64	-51	-39	-26	-14	-1	13	25	38	50	63	75	88	100
Pilots		-84		-60		-36		-12	12		36		60		84	
	e	a	g	c	b	f	d	h	b	f	d	h	e	a	g	c
Subchannels	3	1	4	2	1	3	2	4	1	3	2	4	3	1	4	2
Groupings	B	A	B	A	A	B	A	B	A	B	A	B	B	A	B	A
a	25	1	37	49	61	73	85	97	109	121	133	145	157	13	169	181
	36	12	48	60	72	84	96	108	120	132	144	156	168	24	180	192
b	25	37	49	61	1	73	85	97	13	109	121	133	145	157	169	181
	36	48	60	72	12	84	96	108	24	120	132	144	156	168	180	192
c	25	37	49	1	61	73	85	97	109	121	133	145	157	169	181	13
	36	48	60	12	72	84	96	108	120	132	144	156	168	180	192	24
d	25	37	49	61	73	85	1	97	109	121	13	133	145	157	169	181
	36	48	60	72	84	96	12	108	120	132	24	144	156	168	180	192
e	1	25	37	49	61	73	85	97	109	121	133	145	13	157	169	181
	12	36	48	60	72	84	96	108	120	132	144	156	24	168	180	192
f	25	37	49	61	73	1	85	97	109	13	121	133	145	157	169	181
	36	48	60	72	84	12	96	108	120	24	132	144	156	168	180	192
g	25	37	1	49	61	73	85	97	109	121	133	145	157	169	13	181
	36	48	12	60	72	84	96	108	120	132	144	156	168	180	24	192
h	25	37	49	61	73	85	97	1	109	121	133	13	145	157	169	181
	36	48	60	72	84	96	108	12	120	132	144	24	156	168	180	192
1	49	1	61	73	13	85	97	109	25	121	133	145	157	37	169	181
	60	12	72	84	24	96	108	120	36	132	144	156	168	48	180	192
2	49	61	73	1	85	97	13	109	121	133	25	145	157	169	181	37
	60	72	84	12	96	108	24	120	132	144	36	156	168	180	192	48
3	1	49	61	73	85	13	97	109	121	25	133	145	37	157	169	181
	12	60	72	84	96	24	108	120	132	36	144	156	48	168	180	192
4	49	61	1	73	85	97	109	13	121	133	145	25	157	169	37	181
	60	72	12	84	96	108	120	24	132	144	156	36	168	180	48	192
A	97	1	109	13	25	121	37	133	49	145	61	157	169	73	181	85

	108	12	120	24	36	132	48	144	60	156	72	168	180	84	192	96
B	1	97	13	109	121	25	133	37	145	49	157	61	73	169	85	181
	12	108	24	120	132	36	144	48	156	60	168	72	84	180	96	192

3.4.2 Pilot Usage

As can be seen in the subchannel mapping table, the original 802.16a pilots remain the same. Each of the eight subchannels has one pilot symbol. This can be used for coarse phase offset estimate, which would be followed by a decision directed phase offset estimate.

4. Network Entry with Subchannelization

This section proposes an enhancement to the 802.16a network entry procedures that allows SSs to use subchannels to enter the network, in order to improve the system coverage.

The SS shall use the network entry procedures described in Section 6.2.9.5 in P802.16a/D7-2002 to attempt to enter the system if AP power level and measured RSSI indicate that the link budget is available. If these measurements indicate that power concentration is required, the following subchannel based network entry procedure shall be used by a subchannelization-enabled SS to perform its network entry.

At the next initial ranging opportunity, the SS shall randomly select one subchannel in 1/8 subchannelization mode and use it to send an initial ranging request signal to the AP by using QPSK rate 1/2 with the mandatory coding scheme at the maximum transmission power level. In 1/8 subchannelization mode, an initial ranging request is 3-byte random number, which is also referred to as initial raging code.

If the AP successfully receives and decodes the 1/8 subchannelized initial raging code, it does the following two things:

- It responds by transmitting a range response message (RNG-RSP) that includes SS transmission parameters, but the SS is identified by the frame number and frame opportunity as well as the used initial ranging code when the initial ranging code was received instead of the MAC address of the SS;

- It also allocates a 1/8 subchannelized UL slot for the SS to transmit a normal initial ranging request (RNG-REQ) in the next frame.

When the SS receives the RN-RSP to it by recognizing the frame number, frame opportunity, and initial ranging code when it was sent, it adjusts its transmission parameters and prepares a regular ranging request message (RNG-REQ). When it receives UL-MAP that allocates it an UL slot, it transmits the RNG-REQ message. Then the normal initial ranging procedure starts.

5. Optimal Subchannelization Selection

When the subchannelized network entry is used by a SS, it shall use 1/8 subchannelization to start the initial ranging procedure. However, the 1/8 subchannelization mode may not be the optimal subchannelization mode to the SS. Based on the received UL signal quality, the AP shall select an optimal subchannel mode, e.g., 1/2, 1/4, or 1/8, for the SS and use it in its UL allocations.

6. Bandwidth Requesting with Subchannelization

The SSs that wish to transmit only on subchannels shall not use the REQ Region-Full scheme to send their bandwidth requests. If they need to use the contention-based bandwidth requesting, only the REQ-Region-Focused scheme can be used. To support the proposed subchannelization scheme, the bandwidth request contention codes in Table 116bd shall be allocated to different SSs as follows:

Contention code index	Code allocation	notes
0, 1, and 2	only used by the SSs that wish to transmit in full channel.	
3	Only used by the SSs that wish to transmit in 1/2 subchannel mode.	
4	Only used by the SSs that wish to transmit in 1/4 subchannel mode.	
5, 6, and 7	Only used by the SSs that wish to transmit in 1/8 subchannel mode.	

Based on the received contention code in the phase-1 of the REQ Region-Focused scheme, the AP shall provide the requested allocation in the phase-2 with the requested subchannelization mode, i.e., full channel, 1/2 subchannel, 1/4 subchannel, or 1/8 subchannel.

7. Required MAC Message Changes

The UL-MAP MAC message, and RNG-RES, need to be modified to support the proposed subchannelization scheme.

7.1 UL-MAP Changes

Syntax	Size	Notes
UL-MAP_information_element() {		
CID	16 bits	
UIUC	4bits	
if (UIUC == 4)		
Focused_contention_IE()	28 bits	
else if (UIUC == 15)		
Extended UIUC dependent IE	variable	Power_Control_IE() or AAS_UL_IE() or Subchannelization_IE() or UL_Mobile_IE()
else {		
if (subchannelization) {		
Subchannel Index	4 bits	0x0 = Reserved 0x1 = use subchannel 1 0x2 = use subchannel 2 0x3 = use subchannel 3 0x4 = use subchannel 4 0x5 = use subchannel 5 0x6 = use subchannel 6 0x7 = use subchannel 7 0x8 = use subchannel 8 0x9 = use subchannel 1 and 2 0xA = use subchannel 3 and 4 0xB = use subchannel 5 and 6 0xC = use subchannel 7 and 8 0xD = use subchannel 1, 2, 3, and 4 0xE = use subchannel 5, 6, 7, and 8 0xF = use full channel
Duration	7 bits	in OFDM symbols
Reserved	1 bit	
}		
Else		
Duration	12 bits	
}		
}		

7.2 RNG-RSP

In addition to RNG-RES parameters specified in Section 6.2.2.3.6 in P802.16a/D7-2002, the following WirelessMAN-OFDM PHY specific parameter may also be included in the RNG-RSP message:

- Initial ranging code

  A 3-byte number that was received in the initial ranging slot when a SS used the subchannelization network entry scheme to attempt to enter the network.

8. Recommendataions

We recommend the addition of an 8-subchannel mode as described above. This will provide a modest gain in power without seriously harming throughput or creating a system that is incompatible with 802.16a.

9. References

[1] Call for contributions IEEE 802.16e-02/01: Mobility Enhancements to the IEEE Standard 802.16/802.16/a/c