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Re:	This is a response to a Call for Comments in IEEE802.16e Handover Adhoc
Abstract	In this contribution, the soft handover mechanism is proposed
Purpose	Adoption as part of Handover Adhoc recommendation to IEEE802.16e
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1 Introduction

Soft handover (SHO) in the DL is defined as two or more BSs transmitting the same MAC/PHY PDUs to the MSS at the same time interval such that diversity combining can be performed by the MSS. SHO in the UL is defined as two or more BSs receiving (demodulating, decoding) from the MSS at the same time interval. Diversity combining of the received PHY frames is performed among the BSs.

SHO provides macro-diversity gain which is important in increasing the cell coverage as well as increasing the QoS offering at the cell edge. In addition, in the DL, with soft combining, the inter-cell interference is converted into constructive signal, thus improving the overall SNR.

2 Soft Handover (SHO) Operation

There are several conditions that are required to enable soft handover between MSS and a group of BSs. These conditions are listed below:

- Frames multicast by multiple BSs arrive at the MSS within the prefix interval
- BSs involving in SHO have the same frequency assignment
- BSs involving in SHO have synchronized frame structure
- BSs involving in SHO have level 3 context transfer or sharing, and the same MAC/PHY PDUs shall be multicast by the BSs to the MSS
- BSs involving in SHO shall use the same set of CIDs for the connections that are established with the MSS.

The following concepts are introduced to support SHO. The first one is the Active Set. An Active Set is defined as the list of BSs that are in SHO with the MSS. When a new BS is added to the Active Set; the MSS' capabilities, security parameters, service flows and full MAC context information are either transferred from the existing BSs in the Active Set to the new BS, or shared between the existing BSs in the Active Set and the new BS. The Active Set is updated and maintained by both the MSS and the BS through exchanges of MAC management messages.

The second concept is an Anchor BS. An anchor BS, that is the BS with the strongest signal strength, is defined within the Active Set. The MSS monitors the anchor BS for DL control information, i.e. DL_MAP, UL_MAP, FCH, and DL broadcast messages. For unicast messages and traffic, the MSS is in SHO with the BSs in the Active Set. The MSS shall continuously measure the signal strength of the BSs in its Active Set to determine if a switch in the anchor BS is needed. Once the MSS has decided to switch to another anchor BS, the MSS shall initiate the switching using MAC management messages.

2.1 SHO Procedures

Similar call flow, procedures and HO messages exchange as defined in IEEE802.16e/D3 can be used for setting up the Active Set and Anchor BS for SHO. There are some modifications required on the existing HO messages, mainly to indicate whether the HO is a normal inter-BS HO or a SHO.

The MOB-NBR-ADV message should be modified to provide information about neighbor BSs who can be involved in SHO with the Anchor or Serving BS. The MOB-MSSHO-REQ message should be modified to enable a MSS to request for update of its active set, or request for switching to another Anchor BS. The MOB-BSHO-RSP message shall be modified to indicate the recommended Active Set members based on the MOB-MSSHO-REQ request. In the MOB-BSHO-RSP message, a 3-bit temporary BS ID (TEMP_BS_ID) is assigned to each member BS of the recommended Active Set. This TEMP_BS_ID is used by the MSS and the BS to uniquely identify a BS within the Active Set for the purpose of subsequent HO MAC management messages exchange. The use of TEMP_BS_ID will significantly reduce the overhead compared to the 48-bit BS_ID. The MOB-HO-IND message shall also be modified to enable a MSS to indicate its final Active Set decision.

Similarly, the BS can initiate an update of the Active Set by sending MOB-BSHO-REQ message, which needs to be modified to include the recommended Active Set member and assign the TEMP_BS_ID to each of the member. Similarly, the MOB-MSSHO-RSP needs to be modified to include the recommended Active Set member.

To allow the BSs in SHO to use the same set of CIDs, one approach is to share the CID space among BSs. Alternatively, a new set of CIDs can be assigned to the MSS whenever the new BS to be added to the Active Set has a conflict with the existing CIDs allocated to the MSS. In this way, the CID space needs not be shared among BSs.

3 Proposed Text Changes

3.1 HO Message Modification

[*Modify the Neighbor Advertisement (MOB-NBR-ADV) message, to indicate which neighbor BS can be in SHO with the Serving or Anchor BS*]

6.3.2.3.50 Neighbor Advertisement (MOB-NBR-ADV) message

[…]

Table 92d – MOB-NBR-ADV Message Format

Syntax	Size	Notes
MOB-NBR-ADV_Message_Format () {		
Management Message Type = 49	8 bits	
Operator_ID	24 bits	Unique ID assigned to the operator
N_NEIGHBORS	8 bits	Neighbor BSs excluding BSs declared in SHO_Neighbor for loop
For (I = 0; i < N_NEIGHBORS;i++) {		
Neighbor BS-ID	48 bits	
HO type support	8 bits	Bit 0: Break before Make Bit 1: Make before Break Bit 2: Soft HO Bits 3-7: Reserved, set to 0
if (bit 2 of HO type support is == 1) {		
DL Physical Frequency	32 bits	
Configuration Change Count	8 bits	Incremented each time the information for the associated neighbor BS has changed
TLV Encoded Neighbor information	variable	TLV specific
}		
Preamble_Ind	8 bits	Preamble index (see table 307)
}		
HMAC Tuple	21 bytes	
}		

[…]

Operator ID – the unique network ID shared by an association of BS

Preamble Ind – Preamble index used by the neighbor BS, which will help MSS quickly search neighbor BS

HO type support – Indicates the types of HO supported by the neighbor BS

[…]

[*Modify the MSS HO Request (MOB-MSSHO-REQ) message, to indicate the list of recommended BSs for SHO and provide the necessary CINR information of those BS*]

6.3.2.3.55 MSS HO Request (MOB-MSSHO-REQ) message

[…]

Table 92i- MOB-MSSHO-REQ message Format

Syntax	**Size**	**Notes**
MOB-MSSHO-REQ_Message_Format() {		
Management Message Type = 53	8 bits	
Mode	2 bits	00: HO request 01: SHO request: Anchor BS update 10: SHO request: Active Set update 11: reserved
If (mode == 00) {		
N_Recommended	8 bits	
for (i= 0;i<N_Recommended; i++) {		
Neighbor BS_ID	48 bits	Base station ID
BS CINR mean	8 bits	
}		
Estimated action time	8 bits	The estimated action time shall be the time for the recommended target BS
}		
else if (mode == 01) {		
N_Recommended	8 bits	
for (i= 0;i<N_Recommended; i++) {		
TEMP_BS_ID	3 bits	TEMP_BS_ID of the recommended Anchor BS
BS CINR mean	8 bits	
}		
Estimated action time	8 bits	Estimated action time when the Anchor BS is updated
}		

else if (mode == 10) {		
Anchor_BS_indicator	1 bit	1: the recommended Anchor BS is in the current Active Set 0: the recommended Anchor BS is not in the current Active Set
If (Anchor_BS_indicator == 1) {		
TEMP_BS_ID	3 bits	Active Set member ID of the recommended Anchor BS.
}		
Else {		
Neighbor BS_ID	48 bits	BS_ID of the recommended Anchor BS.
}		
BS CINR mean	8 bits	CINR mean of the Anchor BS
N_new_BSs	3 bits	Number of new BSs (excluding the recommended Anchor BS) which are recommeded to be added to the Active Set of the MSS
For (i= 0; i < N_new_BSs; i++) {		
Neighbor BS_ID	48 bits	
BS CINR mean	8 bts	
}		
N_current_BSs	3 bits	Number of BSs (excluding the recommended Anchor BS) currently in the Active Set of the MSS, which are recommended to be remained in the Active Set
For (i=0;i< N_current_BSs;i++) {		
TEMP_BS_ID	3 bits	Active Set member ID assigned when this BS is added to the Active Set
BS CINR mean	8 bits	
}		
Estimated action time	8 bits	Estimated action time when the Active Set is updated
}		
Reserved	Variable	Pad message to contain an integer number of octets. Pad bits shall be set to 0.
HMAC tuple	21 bytes	
}		

[*Modify the BS HO Response (MOB_BSHO-RSP) message, to indicate the list of recommended BSs for SHO*]

6.3.2.3.56 BS HO Response (MOB_BSHO-RSP) message

[…]

Table 92j- MOB-BSHO-RSP Message Format

Syntax	**Size**	**Notes**
MOB-BSHO-RSP_Message_Format() {		
Management Message Type = 52	8 bits	
Mode	2 bits	00: HO request 01: SHO request: Anchor BS update 10: SHO request: Active Set update 11: reserved
If (Mode == 00) {		
Network Assisted HO supported	1 bit	Indicate that the BS supports Network assisted HO
N_Recommended	8 bits	
For (i= 0;i<N_Recommended; i++) {		
Neighbor BS_ID	48 bits	Base station ID
Service level prediction	8 bits	
}		
}		
else if (Mode == 01) {		
N_Recommended	8 bits	
for (i= 0;i<N_Recommended; i++) {		
TEMP_BS_ID	3 bits	TEMP_BS_ID of the recommended Anchor BS
}		
Estimated action time	8 bits	Estimated action time when the Anchor BS is updated
}		
else if (Mode == 10) {		
Anchor_BS_indicator	1 bit	1: the recommended Anchor BS is in the current Active Set 0: the recommended Anchor BS is not in the current Active Set
If (Anchor_BS_indicator == 1) {		
TEMP_BS_ID	3 bits	Active Set member ID of the

		recommended Anchor BS
}		
Else {		
Neighbor BS_ID	48 bits	BS_ID of the recommended Anchor BS
TEMP_BS_ID	3 bits	Active Set member ID assigned to this BS
}		
Service level prediction	8 bits	Service level predication of the recommended Anchor BS
N_new_BSs	3 bits	Number of new BSs (excluding the recommended Anchor BS) which are recommended to be added to the Active Set of the MSS
For (i= 0; I < N_new_BSs; i++) {		
Neighbor BS_ID	48 bits	
TEMP_BS_ID	3 bts	Active Set member ID assigned to this BS
Service level prediction	8 bits	
}		
N_current_BSs	3 bits	Number of BSs (excluding the recommended Anchor BS) currently in the Active Set of the MSS, which are recommended to be remained in the Active Set
For (i=0;i< N_current_BSs;i++) {		
TEMP_BS_ID	3 bits	Active Set member ID assigned to this BS
Service level prediction	8 bits	
}		
Action time	8 bits	Recommended action time when the Active Set shall be updated
N_CIDs	8 bits	Number of CIDs needed to be reassigned
For (i= 0;i<N_CIDs;i++) {		
Current CID		Currently assigned CID
New CID		New CID to be used after Active Set is updated
}		
}		

Reserved	Variable	Pad message to contain an integer number of octets. Pad bits shall be set to 0.
HMAC tuple	21 bytes	
}		

[*Modify the HO indication (MOB-HO-IND) message, to indicate the decided list of BSs for SHO*]

6.3.2.3.57 HO Indication (MOB-HO-IND) message

[…]

Table 92k- MOB-HO-IND Message Format

Syntax	**Size**	**Notes**
MOB-HO-IND_Message_Format () {		
Management Message Type = 56	8 bits	
Mode	2 bits	00: HO request 01: SHO request: Anchor BS update 10: SHO request: Active Set update 11: reserved
if (Mode == 00) {		
HO_IND_Type	2 bits	00: serving BS release 01: HO cancel 10: HO reject 11: reserved
If (HO_IND_Type == 00) {		
Target_BS_ID	48 bits	
}		
}		
else if (Mode == 01) {		
SHO_IND_Type	2 bits	00: confirm Anchor BS update 01: Anchor BS update cancel 10: Anchor BS update reject 11: reserved
If (SHO_IND_Type == 00) {		
Anchor BS ID	3 bits	TEMP_BS_ID of the Anchor BS
Action_time	8 bits	Action time when the Anchor BS shall be updated
}		
}		
else if (Mode == 10) {		

SHO_IND_Type	2 bits	00: confirms Active Set update 01: Active Set update cancel 10: Active set update reject 11: reserved
If (SHO_IND_Type == 00) {		
Active Set Included Indicator	1 bit	1: Final decision of Active Set members included in the message 0: Active Set members are as specified in MOB_xxHO_RSP message. No Active Set information included in this message.
if (Active Set Included Indicator == 1) {		
Anchor BS ID	3 bits	TEMP_BS_ID of the Anchor BS
N_BS	3 bits	Number of BS in the Active Set, excluding the Anchor BS
for (i = 0; i < N_BS; i++) {		
TEMP_BS_ID	3 bits	Active Set member ID assigned
}		
}		
Action_time	8 bits	Action time when the Active Set shall be updated
}		
}		
Reserved	Variable	Pad message to contain an integer number of octets. Pad bits shall be set to 0.
HMAC tuple	21 bytes	
}		

[*Modify the BS HO Request (MOB-BSHO-REQ) message, to indicate the list of recommended BSs for SHO*]

6.3.2.3.54 BS HO Request (MOB-BSHO-REQ) message

[…]

Table 92h- MOB-BSHO-REQ message Format

Syntax	**Size**	**Notes**
MOB-BSHO-REQ_Message_Format() {		
Management Message Type = 52	8 bits	
Mode	2 bits	00: HO request 01: SHO request: Anchor BS update 10: SHO request: Active Set update 11: reserved
If (Mode == 00) {		

Network Assisted HO supported	1bit	Indicate that the BS supports Network assisted HO
N_Recommended	8 bits	
For (i= 0;i<N_Recommended; i++) {		
Neighbor BS_ID	48 bits	Base station ID
Service level prediction	8 bits	
}		
}		
else if (Mode == 01) {		
N_Recommended	8 bits	
for (i= 0;i<N_Recommended; i++) {		
TEMP_BS_ID	3 bits	TEMP_BS_ID of the recommended Anchor BS
}		
Estimated action time	8 bits	Estimated action time when the Anchor BS is updated
}		
Else if (Mode == 10) {		
Anchor_BS_indicator	1 bit	1: the recommended Anchor BS is in the current Active Set 0: the recommended Anchor BS is not in the current Active Set
If (Anchor_BS_indicator == 1) {		
TEMP_BS_ID	3 bits	Active Set member ID of the recommended Anchor BS.
}		
Else {		
Neighbor BS_ID	48 bits	BS_ID of the recommended Anchor BS.
TEMP_BS_ID	3 bits	Active Set member ID assigned to this BS
}		
Service level prediction	8 bits	Service level prediction of the recommended Anchor BS
N_new_BSs	3 bits	Number of new BSs (excluding the recommended Anchor BS) which are recommended to be added to the Active Set of the MSS
For (i= 0; I < N_new_BSs; i++) {		

Neighbor BS_ID	48 bits	
TEMP_BS_ID	3 bts	Active Set member ID assigned to this BS
Service level prediction	8 bits	
}		
N_current_BSs	3 bits	Number of BSs (excluding the recommended Anchor BS) currently in the Active Set of the MSS, which are recommended to be remained in the Active Set
For (i=0;i< N_current_BSs;i++) {		
TEMP_BS_ID	3 bits	Active Set member ID assigned to this BS
Service level prediction	8 bits	
}		
Estimated action time	8 bits	Action time when the Active Set shall be updated
N_CIDs	8 bits	Number of CIDs needed to be reassigned
For (i= 0;i<N_CIDs;i++) {		
Current CID	16 bits	Currently assigned CID
New_CID	16 bits	New CID to be used after Active Set is updated
}		
}		
Reserved	Variable	Pad message to contain an integer number of octets. Pad bits shall be set to 0.
HMAC tuple	21 bytes	
}		

[*Modify the MSS HO Response (MOB-MSSHO-RSP) message, to indicate the list of recommended BSs for SHO and provide the necessary CINR information of those BS*]

6.3.2.3.xx MSS HO Response (MOB-MSSHO-RSP) message

[…]

Table xx- MOB-MSSHO-RSP message Format

Syntax	**Size**	**Notes**
MOB-MSSHO-RSP_Message_Format() {		
Management Message Type = 59	8 bits	
Mode	2 bits	01: SHO request: Anchor BS

		update 10: SHO request: Active Set update 00, 11: reserved
if (Mode == 01) {		
for (i= 0;i<N_Recommended; i++) {		N_Recommended can be deduced from the known length of the message
TEMP_BS_ID	3 bits	TEMP_BS_ID of the recommended Anchor BS
BS CINR mean	8 bits	
}		
Estimated action time	8 bits	Estimated action time when the Anchor BS is updated
}		
else if (Mode == 10) {		
Anchor_BS ID	3 bit	TEMP_BS_ID of the recommended Anchor BS
Anchor BS CINR mean	8 bits	
N_BS	3 bits	Number of BSs excluding the Anchor BS, in the recommended Active Set
for (i= 0; i < N BSs; i++) {		
TEMP_BS_ID	3 bits	
BS CINR mean	8 bts	
}		
Estimated action time	8 bits	Estimated action time when the Active Set is updated
}		
Reserved	Variable	Pad message to contain an integer number of octets. Pad bits shall be set to 0.
HMAC tuple	21 bytes	
}		

3.2 Additional Text changes

[*Add the following text to section 6.3.20.1.1*]

When working in a SHO mode, a BS shall broadcast information about which neighbor BSs are able to support SHO with this BS, using the MOB-NBR-ADV MAC Management message. The set of conditions required to support SHO among BSs include same frequency assignment, synchronized frame structure, and relative propagation delay less than the prefix interval, among the BSs.

[*Add the following text to section 6.3.20.2, page 47, line 11*]

In addition to the above procedures, when working in a SHO mode, the MSS shall perform the following stages:

- SHO Decision - A soft handover begins with a decision for an MSS to transmit to and receive from multiple BSs at the same time interval.

- Active Set selection– MSS shall scan the neighbors BSs and shall find the BSs which are suitable to work with in the SHO process
- Anchor BS selection – MSS shall shall select one BS from its current Active Set to be the Anchor BS in the SHO process.

[*Add a section 6.3.20.2.6*]

6.3.20.2.6. SHO Decision and Initiation

A soft handover begins with a decision for an MSS to transmit to and receive from multiple BSs at the same time interval. For DL SHO, two or more BSs provide synchronized transmission of MSS downlink data such that diversity combining can be performed by the MSS. For UL SHO, the transmission from a MSS is received by multiple BSs such that diversity combining of the information received by multiple BSs can be performed. The decision may originate either at the MSS, or at the BS.

While in SHO, the MSS and the BS or network maintain the list of BSs that are involved in SHO with the MSS. The list is called the Active Set. Among the BSs in the Active Set, an Anchor BS is defined. The MSS monitors the Anchor BS for DL control information, i.e. DL_MAP, UL_MAP, FCH, and DL broadcast messages. For unicast messages and traffic, the MSS is in SHO with the BSs in the Active Set. The decision of entering SHO or updating the Active Set, or updating the Anchor BS shall begin with a notification by the MSS through the MOB-MSSHO-REQ MAC management message or by the BS through the MOB-BSHO-REQ management message. Acknowledgement with MOB-BSHO-RSP of a notification is required, but one with MOB-MSSHO-RSP is recommended by not required.

If an MSS that transmitted a MOB-MSSHO-REQ message detects an incoming MOB-BSHO-REQ message, it may respond with a MOB-MSSHO-RSP message and ignore its own request. Similarly, a BS that transmitted a MOB-BSHO-REQ message shall ignore any MOB-MSSHO-REQ messages from the same MSS and shall await a MOB-MSSHO-RSP message or MOB-HO-IND message, or retry the MOB-BSHO-REQ message.

The BSs involving in SHO with a MSS shall use the same set of CIDs for the connections that are established with the MSS. BS may assign a new set of CIDs to the MSS during Active Set update through MOB-BSHO-REQ message and MOB-BSHO-RSP message.

6.3.20.2.6.1 Active Set Update

When MOB-MSSHO-REQ is sent by an MSS, the MSS may indicate possible list of BSs to be included in the MSS' Active Set. The MSS may evaluate the possible list of BSs through the received MOB-NBR-ADV MAC management message, and previously performed signal strength measurement, propagation delay measurement, scanning, ranging, and association activity. When MOB-BSHO-RSP is sent by the Serving BS or BSs in the MSS' current Active Set, the BSs may indicate the recommended list of BSs to be included in the MSS' Active Set.

When MOB-BSHO-REQ is sent by the Serving BS or BSs in the MSS' current Active Set, the BSs may indicate the recommended list of BSs to be included in the MSS' Active Set. The BSs criteria for the recommendation may include factors such as expected recommended BSs QoS performance to MSS requirements and list of BSs that can be involved in SHO as broadcast in MOB-NBR-ADV. When MOB-MSSHO-RSP is sent by the MSS, the MSS may indicate the recommended list of BSs to be included in the MSS' Active Set. The MSS criteria for the recommendation may include factors such as previously performed signal strength measurement, propagation delay measurement, scanning, ranging, and association activity.

MSS actual pursuit of soft handover with the Active Set BSs listed in MOB_xxxHO-RSP is recommended, but not required. However, the actual Active Set chosen by the MSS shall be a subset of those listed in MOB_xxxHO-RSP and shall be indicated in MOB-HO-IND, with SHO_IND_type field in MOB-HO-IND set to '00'(confirm Active Set update). The MSS may reject the SHO instruction by the BS, by setting the SHO_IND_type field in MOB-HO-IND to '10' (Active Set update reject). The BS may reconfigure the Active Set BSs list and retransmit MOB-BSHO-RSP message to the MSS.

After an MSS or BS has initiated a SHO Active Set update using MOB-MSSHO/BSHO-REQ, the MSS may cancel SHO Active Set update at any time. The cancellation shall be made through transmission of a MOB-HO-IND with SHO_IND_type field set to '01'.

When adding a new BS to the MSS' Active Set, the network entry procedures as depicted in Figure 130h are not required and shall not be performed by the MSS.

6.3.20.2.6.1 Anchor BS Update

When MOB-MSSHO-REQ is sent by an MSS, the MSS may indicate one or more possible Anchor BSs. The list of possible Anchor BSs shall be within the current Active Set of the MSS. The MSS may evaluate the list of possible Anchor BSs through the previously performed signal strength measurement. When MOB-BSHO-RSP is sent by the Serving BS or BSs in the MSS' current Active Set, the BSs may indicate the recommended Anchor BS.

When MOB-BSHO-REQ is sent by the Serving BS or BSs in the MSS' current Active Set, the BSs may indicate one or more recommended Anchor BSs. When MOB-MSSHO-RSP is sent by the MSS, the MSS may the recommended Anchor BS. The MSS criteria for the recommendation may include factors such as previously performed signal strength measurement.

MSS actual pursuit of Anchor BS update with the Anchor BS listed in MOB_xxxHO-RSP is recommended, but not required. However, the actual Anchor BS chosen by the MSS shall be within the MSS' current Active set. The MSS shall indicate the chosen Anchor BS in MOB-HO-IND, with SHO_IND_type field in MOB-HO-IND set to '00'(confirm Anchor BS update). The MSS may reject the Anchor BS update instruction by the BS, by setting the SHO_IND_type field in MOB-HO-IND to '10' (Anchor BS update reject). The BS may reconfigure the Anchor BS list and retransmit MOB-BSHO-RSP message to the MSS.

After an MSS or BS has initiated a SHO Anchor BS update using MOB-MSSHO/BSHO-REQ, the MSS may cancel SHO Anchor BS update at any time. The cancellation shall be made through transmission of a MOB-HO-IND with SHO_IND_type field set to '01'.

When switching to a new Anchor BS within the MSS' Active Set, the network entry procedures as depicted in Figure 130h are not required and shall not be performed by the MSS.

[*Add a new section 11.7.10.2*]

11.7.10.2 Soft handoff supported

This field indicates whether or not the MSS supports SHO. A bit value of 0 indicates "not supported" while 1 indicates it is supported.

Type	Length	Value
19	1	Bit #0: SHO supported Bits #1-7: reserved; shall be set to zero