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| Re: | Call for inputs for the Handoff Ad-hoc group |
| Abstract | This document is the output of the Handoff ad-hoc group. The document describes a set of messages and parameters for handoff MAC level and PHY independent support for the 802.16e mobile group. |
| Purpose | Handoff Ad Hoc draft proposal for the IEEE802.16e group. |
| Notice |  |
| Release |  |
| Patent Policy and Procedures |  |

# Handoff mechanism for IEEE 802.16e

## HO parameters and definitions

### *Definitions*

**Mobile Subscriber Station (MSS)** – IEEE 802.16e based SS that supports mobile functionality. [This terms requires its own definition. It is suggested that we revise this definition in a later stage].

**Base Station Sector (BS)** – Part of an IEEE 802.16e BS, which provides a single instance of the IEEE802.16e air-interface on a single radio frequency channel. [This definition may be superfluous, if we don't have any entity operating at the multi-sector level. It is suggested that we revise this definition in a later stage].

**Handoff (HO)** – The process in which a MSS migrates from the air-interface provided by one BS to the air-interface provided by another BS. Two HO variants are defined,

- Hard HO - A HO where service with the new BS starts after a disconnection of service with the old BS.
- Soft HO - A HO where service with the new BS starts before disconnection of the service with the old BS.

**Serving BS** – For any MSS, the serving BS is the BS with which the MSS has recently performed registration at initial network-entry or during an HO.

**Target BS** – The BS that a MSS intends to be registered with at the end of a HO.

**Neighbor BS** – For any MSS, a neighbor BS is a BS whose downlink transmission can be demodulated by the MSS.

**Scanning Interval** – A time period intended for monitoring neighbor BS by the MSS, to determine their suitability as targets for HO.

**Monitored BS** – A BS that is monitored by the MSS during its scanning interval.

**Selected BS** – A subset of Monitored BS, which is selected as potential Target BS.

## Network reference model

### *Entities*

The network reference model consists of BS units covering a certain area, and connected by a backbone network. Several such networks, owned by different operators may coexist in the same service area. Each backbone network may contain centralized AAA, management, provisioning or other specialized servers. Specifically, those servers responsible for authentication and service authorization are collectively referred to as ASA-server(s) and may be single, multiple, centralized or distributed. The operation of these servers with the BS and MSS is specified to the extent of defining the control messages. [Should transport protocol(s) be defined as well, or at least recommended?].

| Reference Point | Elements to be Specified by 802.16E |
|---|---|
| MSS | Mobile Subscriber Station, contains MAC (CS), PHY layers |
| BS | Base Station Sector: a single MAC entity covers a single sector. BS, at the network side, supports functionality similar to Foreign Agent of Mobile IP working in "foreign agent care-of address" mode. |
| ASA Server(s) | Authentication and Service Authorization Server servicing the whole operator's network. These servers are optional, and may be implemented as a distributed entity. |

Table 1: Mobility Related Entities

Figure 1 shows an example of such a network, where two networks operated by different operators coexist in the same service area. BS #1 is the serving BS for the depicted MSS. BS #2 and BS #3 are neighbor BS. Should the depicted MSS move closer to BS #2, as drawn by dotted line BS #2 might be the target BS for an HO. Should the depicted MSS continue movement into the area covered the by BS #3, it might perform HO to that BS. [Should this situation be considered HO, or network re-entry in a different network?].

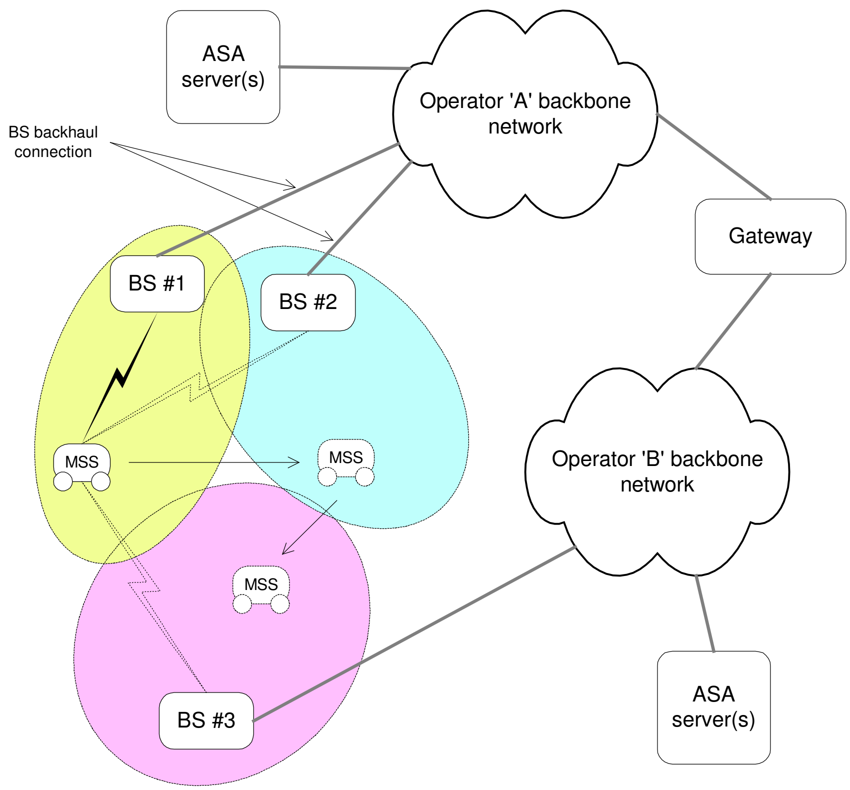


Figure 1: Network model example

Figure 2 shows the network reference model in the data plane.

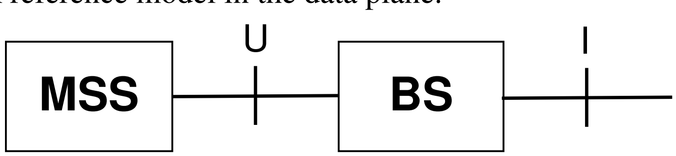

Figure 2: Network reference model, Data Plane

The following reference points are present data plane network model,

| Reference Point | Elements to be Specified by 802.16E | Comments |
|---|---|---|
| U | PHY, MAC (including CS) operations | |
| I | None | This point corresponds to data backbone |

Table 2: Reference Points at Data Plane

Figure 3 shows the network reference model in the control plane.

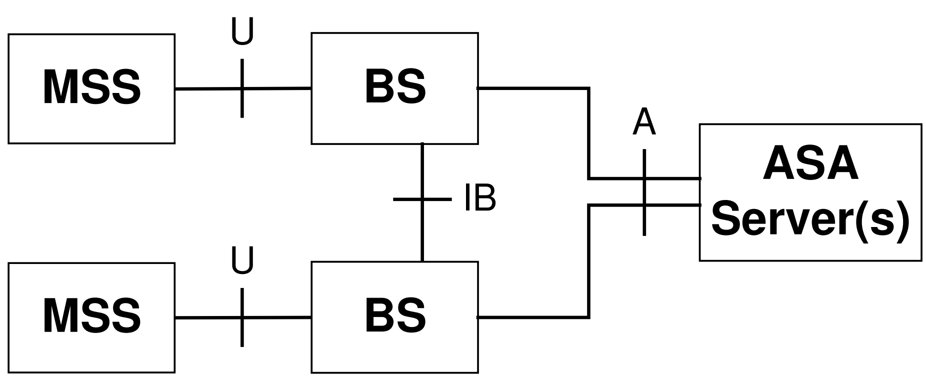


Figure 3: Network reference model, Control Plane

The following reference points are present at the control plane network model

| Reference Point | Elements to be Specified by 802.16E | Comments |
|---|---|---|
| U | PHY, MAC (including CS) operations, Mobility Sub-layer messages exchange | |
| IB | BS-to-BS messages | Transport protocol is not specified |
| A | Messages serving MSS authentication and service authorization functions | Transport protocol is not specified |

Table 3: Reference Points at Control Plane

**Note**: In the case a BS is implemented as a set of BS controlled by a single central controller, IB reference point is located in the controller. This makes inter-cell and intra-cell HO indistinguishable.

### *MSS Protocol Stack*

No difference here compared to IEEE 802.16a standard.

### *BS Protocol Stack*

[Should 802.16e specify data backbone protocols and features that support mobility at the backbone? Some reasons to avoid this are,

1) It is out of scope of 802.16E project
2) It would make our work dependent on choices that are yet to be taken by the industry

Instead, certain assumptions could be taken on the nature of the backbone that allows specifying primitives for communication between MAC (CS) and mobility function located at BS. It might be worthwhile to detail these assumptions in a separated informative section (addendum?) and include examples of specific IP mobility technologies (Mobile IP or Mobile IP/HAWAII etc.)]

The following picture displays BS protocol stack

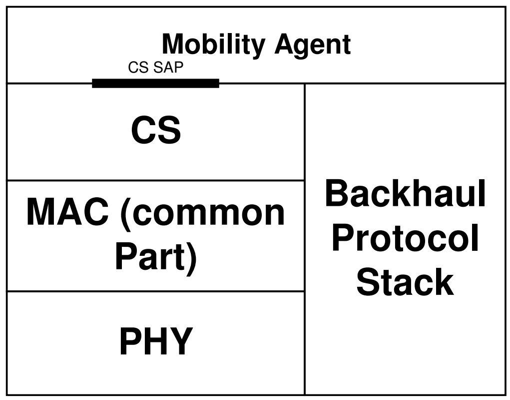


Figure 4: BS Protocol Stack

### Mobility Agent (MA) Operations

In addition to regular 802.16 layers, the stack contains Mobility Agent (MA) layer. The functions of MA are similar to functions of Foreign Agent of Mobile IP working in "foreign agent care-of address" mode. Nevertheless, we avoid direct specification of Mobile IP as a protocol that implements mobility features from the backbone side.

MA provides the following functions,

- Termination of tunnel carrying data from MSS home network including de-capsulation of incoming data units
- Communication to CS about
    - After arrival of new MSS to the cell, creation of new connections. This includes
        - Creation of new classifier(s) to forward data to the connections
        - Specification of proper QoS per connection
    - After MS departure, deletion of connections and classifiers

### Primitives for Communication Between CS and MA

*MA to CS: CS_CREATE_CONNECTION.request/response*

Generated to trigger creation of new connection servicing a newly arrived MSS; specifies classifier(s) to forward data to the connections and QoS parameters for the connection

[TBD Parameters]

*MA to CS: CS_TERMINATE_CONNECTION.request/response*

Generated to trigger termination of connection(s) after a MSS leaves the cell

[TBD Parameters]

*MA to CS: CS_SDU.request*

Generated to send an SDU to backbone connection

[TBD Parameters]

*CS to MA: CS_MSS_ARRIVAL.indication*

Signals MSS arrival at the cell

[TBD Parameters]

*CS to MA: CS_MS_DEPARTURE.indication*

Signals MSS departure from the cell

[TBD Parameters]

*CS to MA: CS_SDU.indication*

Generated to signal arrival of an SDU from the backhaul connection

[TBD Parameters]

## MSS Service Context

*Network Service* is defined as a service provided to the MSS by the network through a single MAC connection with particular connectivity and MAC parameters (including QoS properties). Connectivity properties are defined by specification of MSS network address in its Home Network [This term is undefined].

*MSS Service Context* specifies the set of network services authorized for a given MSS. It is composed of the following elements:

| Context Element | Meaning |
|---|---|
| **MSS 48-bit MAC address unique identifier** | 48-bit unique identifier used by MSS on initial network. This ID does not change while MSS passes from one BS to another. During HO it is used to refer to specific connectivity (addressing) and properties of MAC connections (including QoS properties) |
| **Number N of Network Service IEs** | Number of Network Service Information Elements (NSIEs). Each SIE corresponds to a single data connection |
| **N x NSIE** | The structure of SIE is specified below |
| **Number M of Security Association** | Number M of Security Associations established for the MSS. |
| **M x SAIE** | *TBD* |

Table 4: MAC service context

| Field | Meaning |
|---|---|
| **Address of MSS at Home Network** | IP address of MSS at its Home Network. This address does not change while MSS travels from one BS to another. [?] |
| **MAC Connection Parameters** | Connection parameters as specified in [1], section 6.1.1.1.2 |

Table 5: Service Information Element (SIE) contents

## Transfer of Control Information During HO

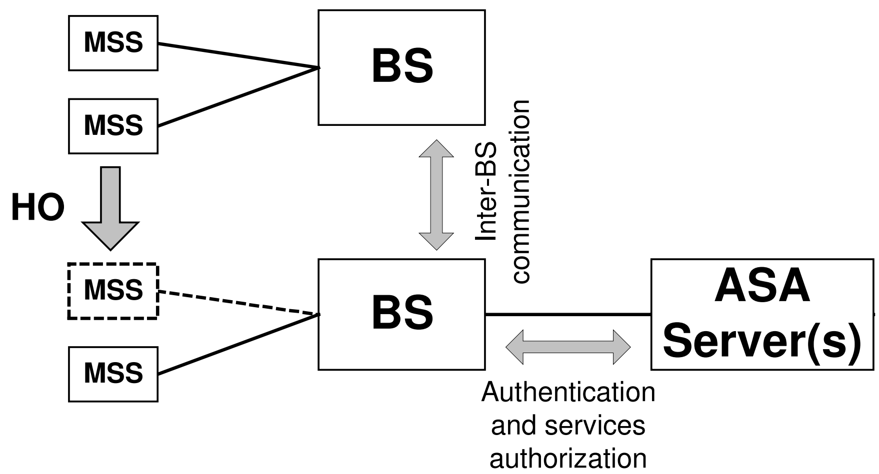


Figure 5: Network Structure (Control Plane) and HO

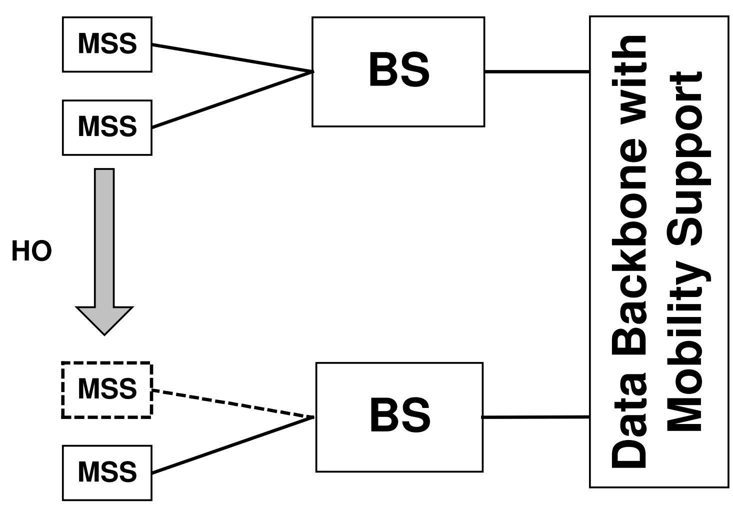


Figure 6: Network Structure (Data Plane) and HO

## MAC layer HO procedures

This section contains the procedures performed during HO on the air-interface.

### *Network topology acquisition*

#### Network topology advertisement

A BS shall broadcast information about the network topology using the NBR-ADV MAC message. MSS may decode this message to find out information about the parameters of neighbor BS. Each MSS will thus be able to synchronize quickly with neighbor BS. [It should be noted in this respect that the neighbor BS are defined as those a MSS could receive. This means that a BS does not know its neighbors unless told by its MSS or by the management layer. We should define how the BS is told who are its neighbors].

### MSS Scanning of neighbor BS

A BS may allocate time intervals to MSS for the purpose of seeking and monitoring neighbor BS suitability as targets for HO. Such a time interval will be referred to as a **scanning interval**.
A MSS may request an allocation of a scanning interval using the SCN-REQ MAC message. The MSS indicates in this message the duration of time it requires for the scan, based on its PHY capabilities.
Upon reception of this message, the BS shall respond with placement of a Scanning_IE in the DL-MAP. The Scanning_IE shall either grant the requesting MSS a scanning interval that is at least as long as requested by that MSS, or deny the request. The BS may also place unsolicited Scanning_IE.
A MSS, upon detection of a Scanning_IE addressed to it in the DL-MAP, shall use the allocated interval to seek for neighbor BS. When neighbor BS are identified, the MSS shall attempt to synchronize with their downlink transmissions, and estimate the quality of the PHY connection.

A MSS may use this interval for UL ranging as well to in a procedure is called **association**. When associating with a neighbor BS, the MSS shall not only synchronize with neighbor BS downlink, but shall also perform two additional stages called **association-initial-ranging** and **association-pre-registration**. Association-initial-ranging is performed by transmitting a RNG-REQ MAC message as specified in [1] section 6.2.9.5 with the extensions specified in section 0. Upon reception of a RNG-RSP message with the **prediction of service level** parameter set to 2, the MSS marks the target BS as Associated. Information on Association is reported to the Serving BS [How?]. The target BS may store information on newly associated MSS. Association state of specific MSS at the BS shall be aged-out after TBD timeout.

## *HO process*

The section defines the HO process in which a MSS migrates from the air-interface provided by one BS to the air-interface provided by another BS. The HO process belongs to the break-before-make type and consists of the following stages:

1. HO initiation, the decision to start the process is taken
2. Termination of service with the serving BS, where all connections belonging to the MSS are terminated, and the context associated with them (i.e. information in queues, ARQ state-machine, counters, timers, etc.) is discarded
3. Network re-entry in target BS, where the MSS re-enters the network using a fast network entry procedure. After network re-entry, connection belonging to the MSS are re-established based on the availability of resources in the target BS.

The HO process, and its similarity to the initial network entry process, is depicted in Figure 7.

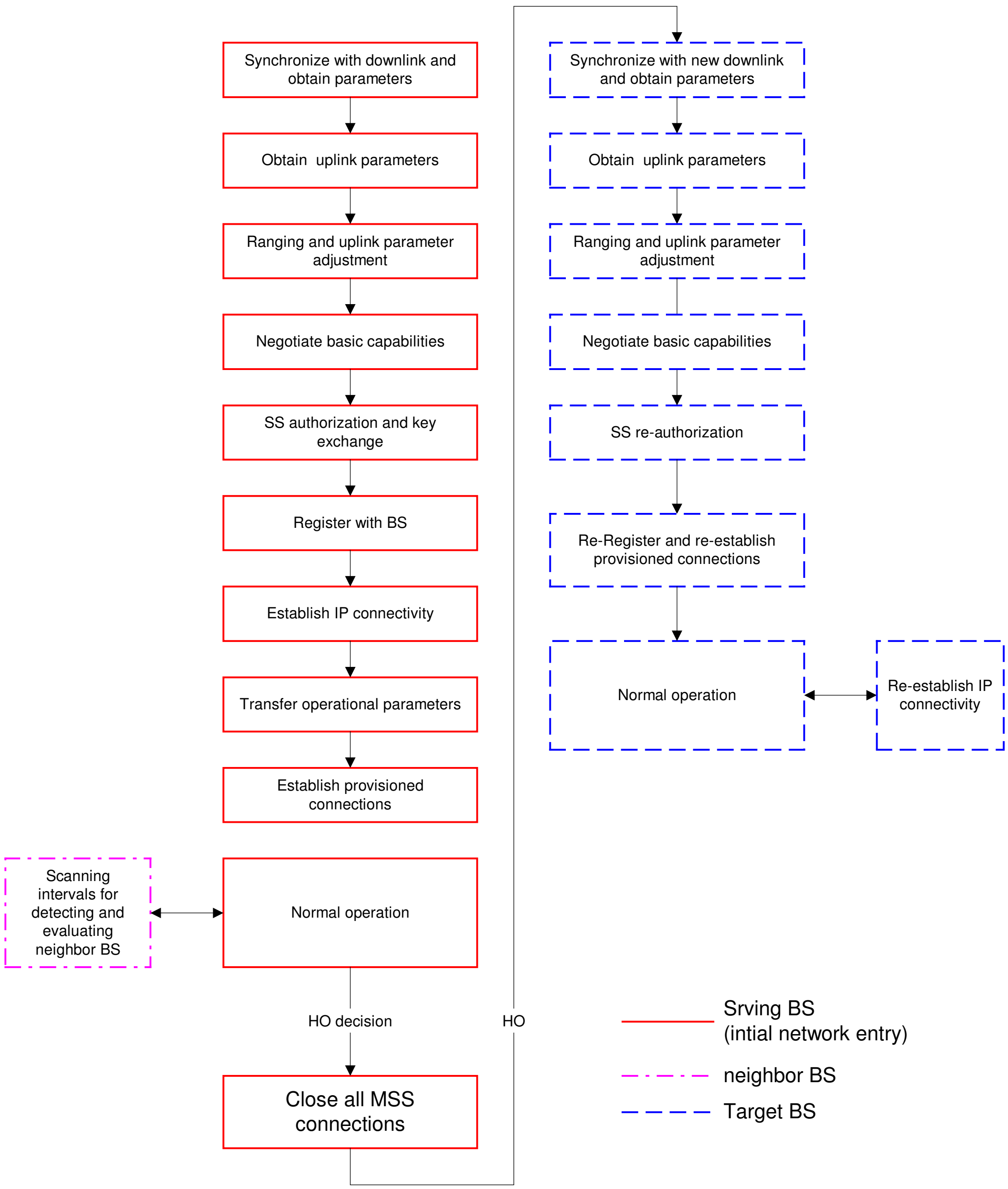


Figure 7: HO and initial network entry

### HO initiation

Either a MSS or a BS may initiate a HO by transmitting the HO-REQ MAC message. It is anticipated that in most situations the MSS will be the initiator of the HO, but sometimes a BS may be the initiator of a HO to facilitate load sharing among BS.
When HO-REQ is sent by a MSS, the MSS may indicate possible target BS (from signal quality point of view). When sent by a BS, the BS may indicate the recommended target BS (based on their capability to meet the MSS QoS requirements). The HO-REQ message may include an indication of the estimated time for performing the HO.
At the BS side, before sending or after receiving a HO-REQ message, the BS shall notify neighboring BS through the backbone of the HO request. The BS shall further acquire from the neighbor BS information regarding their capability of serving the requesting MSS. See section 0 for specification of the communication through the backbone network, and the information exchanged between BS.

After receiving HO-REQ message, the receiving party shall respond with a HO-RSP MAC message. When sent by a BS, the HO-RSP message may indicate a recommended target BS. The MSS, at the risk that if it chooses an alternative target BS, it might receive a degraded level of service, may ignore this recommendation (this includes staying with its serving BS, i.e. skipping the HO). The HO-RSP message may also includes an estimation of the time when the HO would take.

### Termination with the serving BS

After the HO-REQ/RSP handshake is completed, the MSS may begin the actual HO by closing all connections to the serving BS. This mass destruction act is done by sending a DEL-ALL MAC message.
Upon reception of a DEL-ALL MAC message, the BS may close all connections and discard MAC state machines and MPDUs associated with the MSS. [Note the BS does not HAVE to close or discard anything, this enables a make-before-break HO].

### Drops and corrupted HO attempts

A drop is defined as the situation where a MSS has stopped communication with its serving BS (either in the downlink, or in the uplink) before the normal HO sequence outlined in 30 and 0 has been completed.
A MSS can detect a drop by its failure to demodulate the downlink, or by exceeding the RNG-REQ retries limit allowed for the periodic ranging mechanism. A BS can detect a drop by exceeding the RNG-REQ retries limit allowed for the periodic ranging mechanism. [Figures 56 and 55 in IEEE 802.16-2001 and the associated timers should be amended in this context to allow faster drop detection].
When the MSS has detected a drop, it shall attempt network re-entry with its preferred target BS as outlined in section 0. When the BS has detected a drop, it shall react as if a DEL-ALL MAC message has been received from the dropped MSS.

### Re-entry with the target BS

When re-entry with the target BS takes place, the target BS as well as all neighbor BS are aware of the HO in progress (except in a drop situation). At re-entry, the MSS performs the steps as shown in Figure 7.

*Synchronize with downlink and obtain parameters*
For MSS that have used their scanning interval to synchronize with target BS and have decoded the NBR-ADV message, this stage should be immediate. In other situations this procedure defaults to the one specified for initial network entry. [Should we mandate a limit here? The limit would have to consider DCD-Interval parameter].

*Obtain uplink parameters*
For MSS that have decoded the NBR-ADV message, this stage should be immediate. In other situations this procedure defaults to the one specified for initial network entry. [Should we mandate a limit hear? The limit would have to consider UCD-Interval parameter].

*Ranging and uplink parameters adjustment*
For MSS that have used their scanning interval to do UL ranging with target BS this stage should be immediate. Otherwise, this stage is similar to the one performed at initial network entry. During this stage the MSS is assigned a new basic and primary management CID in the target BS.
As opposed to initial network entry, where this stage is performed on contention basis, here the ranging opportunity may be allocated individually by the BS based on a MSS 48-bit MAC address identifier. This identifier is forwarded to the target BS via the backbone network (see section 0). This is done using the Fast_UL_ranging_IE() (see 0) in the UL-MAP. When an initial ranging opportunity is not allocated individually, this procedure defaults to the one specified for initial network entry.

*Negotiate basic capabilities*
This stage is identical to the one performed during initial network entry. [This handshake could be skipped if we could agree on a set of capabilities that are met by all MSS implementing the mobile profile. This would reduce flexibility, but would reduce HO time by at-least two frames].

*MSS re-authorization*
During this stage the MSS performs the re-authorization part of the PKM protocol used at initial network entry (see [1] section 7.2). The BS authenticates the user and as the security context has not changed (it is transferred from the old BS via backbone, see section 0) the security sub-layer can continue in normal operation.
[More details should be provided here]

*Re-register and re-establish provisioned connections*
This stage is equivalent to several stages performed during initial network entry. In this stage the MSS re-registers with the BS, and receives on the registration response a conversion table that maps the connections it had with its pervious serving BS to a new set of connections on the current serving BS. In doing so, the MSS skips the **establish-IP-connectivity** stage, where it is assigned an IP address for management purposes. This stage is not really skipped during HO, instead it is postponed until the normal-operation stage is reached. The **transfer-operational-parameters** and the **time-of-day establishment** stage are skipped as none of the information contained in the configuration file, nor the time-of-day is expected to change.
The MSS attempts the re-registration by sending the normal REG-REQ MAC message. At this stage the MSS has already provides its 48-bit MAC address identifier, and the BS can recognize that the MSS is performing a HO. The BS REG-RSP shall therefore include TLV values for re-establishing the provisioned connections (see section 0).

*Commence normal operation*
At this stage normal operation commences. The MSS shall re-establish its IP connectivity as specified at initial network entry. **Figure 8** shows how a complete HO process might look like in the time domain.

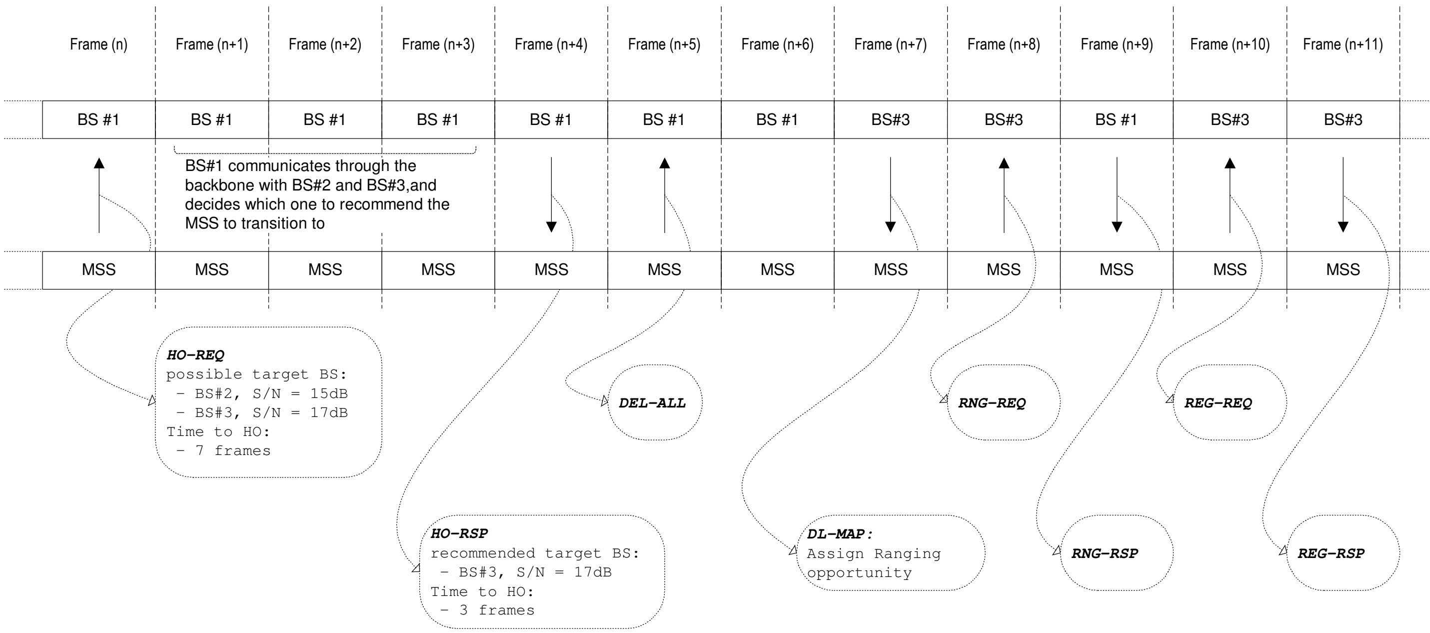


**Figure 8: View of a HO process in the time domain**

### HO completion

[This section should discuss the following:

- Post HO operations (mostly applicable if make-before-break HO is supported)

]

## MAC messages for HO

### *Neighbor Advertisement (NBR-ADV) message*

An NBR-ADV message shall be broadcasted by a BS at a periodic interval (Table 19) to define the characteristics of neighbor BS.

The message parameters following the configuration change count shall be encoded in a TLV format in which the type and length fields are each 1 byte long.

| Syntax | Size | Notes |
|---|---|---|
| NBR-ADV_Message_Format() { | | |
| **Management Message Type = ?** | 8 bits | |
| **N_NEIGHBORS** | 8 bits | |
| For (j=0 ; j<N_NEIGHBORS ; j++) { | | |
| **Neighbor BS-ID** | 48 bits | |
| **Configuration Change Count** | 8 bits | |
| **Physical Frequency** | 16 bits | |
| **TLV Encoded Neighbor information** | Variable | TLV specific |
| } | | |
| } | | |

Table 6: NBR-ADV message format

A BS shall generate NBR-ADV messages in the format shown in Table 6. The following parameters shall be included in the NBR-ADV message,

**N_Neighbors** – Number of advertised neighbor BS

For each advertised neighbor BS, the following parameters shall be included,

**Neighbor BS-ID** – Same as the **Base Station ID** parameter in the DL-MAP message of neighbor BS

**Configuration Change Count –** Incremented by one (modulo 256) whenever any of the values relating to this neighbor BS change. If the value of this count in a subsequent NBR-ADV message remains the same, the MSS can quickly to disregard the TLV encoded information

**Physical Frequency –** Physical frequency in multiples of 0.1MHz

All other parameters are coded as TLV value (see Table 20).
For each advertised neighbor BS, the following TLV parameters may be included,

**DCD_settings** – The DCD_settings is a compound TLV value that encapsulates a DCD message that may be transmitted in the advertised BS downlink channel. This information is intended to enable fast synchronization of the MSS with the advertised BS downlink.

**UCD_settings –** The UCD_settings is a compound TLV value that encapsulates a UCD message that may be transmitted in the advertised BS downlink channel. This information is intended to enable fast synchronization of the MSS with the advertised BS uplink.

## *Scanning Interval Allocation Request (SCN-REQ) message*

An SCN-REQ message may be transmitted by a MSS to request a scanning interval for the purpose of seeking neighbor BS, and determining their suitability as targets for HO.

| Syntax | Size | Notes |
|---|---|---|
| SCN-REQ_Message_Format() { | | |
| **Management Message Type = ?** | 8 bits | |
| **Scan Duration** | 20 bits | For SCa PHY, units are mini-slots.<br>For OFDM/OFDMA PHY, units are OFDM symbols |
| } | | |

Table 7: SCN-REQ message format

A MSS shall generate SCN-REQ messages in the format shown in Table 19. The following parameters shall be included in the SCN-REQ message,

**Scan Duration –** The requested period of time for the scan. The units are PHY-dependent, as specified in Table 7. [Should scan duration be specified in frames?]

## *Scanning Information Element*

A Scanning_IE shall be placed in the DL-MAP message by a BS in response to an SCN-REQ message sent by a MSS. The Scanning_IE shall be placed in the extend DIUC (extension code = ?) within a DL-MAP IE. A value

of zero in the Scan Duration field shall be interpreted as denial of the SCN-REQ. A BS may also send an unsolicited Scanning_IE.
The format of the IE is PHY dependent as shown in Table 8.

| For SCa PHY: | | |
|---|---|---|
| **Syntax** | **Size** | **Notes** |
| `Scanning_IE {` | | |
| **`CID`** | 16 bits | MSS basic CID |
| **`Scan Start`** | 22 bits | Offset (in units of mini-slots) to the start of the scanning interval from the mini-slot boundary specified by the downlink Allocation_Start_Time |
| **`Scan Duration`** | 22 bits | Duration (in units of mini-slots) where the MSS may scan for neighbor BS. |
| `}` | | |

| For OFDM PHY: | | |
|---|---|---|
| **Syntax** | **Size** | **Notes** |
| `Scanning_IE {` | | |
| **`CID`** | 16 bits | MSS basic CID |
| **`Scan Start`** | 18 bits | Indicates the scanning interval start time, in units of OFDM symbol duration, relative to the start of the first symbol of the PHY PDU (including preamble) where the DL-MAP message is transmitted. |
| **`Scan Duration`** | 18 bits | Duration (in units of OFDM symbols) where the MSS may scan for neighbor BS. |
| `}` | | |

| For OFDMA PHY: | | |
|---|---|---|
| **Syntax** | **Size** | **Notes** |
| `Scanning_IE {` | | |
| **`CID`** | 16 bits | MSS basic CID |
| **`Scan Start`** | 18 bits | The offset of the OFDM symbol in which the scanning interval starts. Measured in OFDM symbols from the time specified by the Allocation_Start_time field in the DL-MAP |
| **`Scan Duration`** | 18 bits | Duration (in units of OFDM symbols) where the MSS may scan for neighbor BS. |
| `}` | | |

Table 8: Scanning_IE format

## *Ranging Request/Response RNG-REQ/RSP*

[This text should be added to section 6.2.2.3.5 in [1]]
A MSS may use the RNG-REQ message in its scanning interval for associating with a neighbor BS. When associating with a neighbor BS, the MSS shall send the RNG-REQ message with the following parameters,

**Downlink Channel ID –** The identifier of the downlink channel on which the MSS received the UCD describing the uplink on which this ranging request message is to be transmitted. This is an 8-bit field.

**SS MAC Address –** A 48-bit unique identifier for the MSS.

**CID at MAC Header –** Shall always the Initial Ranging CID.

**MSS Association Channel ID –** An identifier of the downlink channel on which the MSS is currently registered. This is an 8-bit field.

[This text should be added to section 6.2.2.3.6 in [1]]
When a BS sends a RNG-RSP message in response to a RNG-REQ message containing a **MSS Association Channel ID TLV,** The BS may include the following parameter in the RNG-RSP message,

**Service Level Prediction –** This value indicates the level of service the MSS can expect from this BS. The following encodings apply:
0 = No service possible for this MSS
1 = Service requested (as determined by the 48-bit MSS MAC address) is available
2 = Service request at requested QoS level is available
This is an 8-bit field.

## *HO Request (HO-REQ) message*

Either a MSS or a BS may transmit an HO-REQ message when either wants to initiate an HO. The message shall be transmitted on the basic CID.

| Syntax | Size | Notes |
|---|---|---|
| `HO-REQ_Message_Format() {` | | |
| **`Management Message Type = ?`** | 8 bits | |
| **`Estimated HO time`** | 8 bits | |
| **`N_Recommended`** | 8 bits | |
| `For (j=0 ; j<N_NEIGHBORS ; j++) {` | | |
| **`Neighbor BS-ID`** | 48 bits | |
| **`BS S/(N+I)`** | 8 bits | This parameter exists only when the message is sent by the MSS |
| `}` | | |
| `}` | | |

Table 9: HO-REQ message format

A BS or MSS shall generate HO-REQ messages in the format shown in Table 9. The following parameters shall be included in the HO-REQ message,

**Estimated HO time** – Estimated number of frames until the HO will take place. A value of zero in this parameter signifies that this parameter should be ignored.

**N_Recommended –** Number of recommended neighbor BS

For each recommended neighbor BS, the following parameters shall be included,

**Neighbor BS-ID** – Same as the **Base Station ID** parameter in the DL-MAP message of neighbor BS

**BS S/(N + I)** – This parameter exists only when the MSS sends the HO-REQ message. The parameter indicates the signal to noise and interference ratio measured by the MSS from the particular BS. The value shall be interpreted as an unsigned byte with units of 0.25dB. A value of zero in this parameter signifies that this parameter should be ignored.

## HO Response (HO-RSP) message

Either a MSS or a BS shall transmit an HO-RSP message upon reception of HO-REQ message. The message shall be transmitted on the basic CID.

| Syntax | Size | Notes |
|---|---|---|
| HO-RSP_Message_Format() { | | |
| **Management Message Type = ?** | 8 bits | |
| **Estimated HO time** | 8 bits | |
| **N_Recommended** | 8 bits | |
| For (j=0 ; j<N_NEIGHBORS ; j++) { | | |
| **Neighbor BS-ID** | 48 bits | |
| **BS rating** | 8 bits | This parameter exists only when the message is sent by the BS |
| } | | |
| } | | |

Table 10: HO-RSP message format

A BS or MSS shall generate HO-RSP messages in the format shown in Table 10. The following parameters shall be included in the HO-RSP message,

**Estimated HO time** – Estimated number of frames until the HO will take place. A value of zero in this parameter signifies that this parameter should be ignored.

**N_Recommended –** Number of recommended neighbor BS

For each recommended neighbor BS, the following parameters shall be included,

**Neighbor BS-ID** – Same as the **Base Station ID** parameter in the DL-MAP message of neighbor BS

**BS rating** – This parameter exists only when the BS sends the HO-RSP message. The parameter indicates the relative level to which the target BS could meet the MSS QoS requirements [How exactly will this parameter be calculated?]. A value of zero in this parameter signifies that this parameter should be ignored.

## Delete All Connections (DEL-ALL) message

A MSS may transmit a DEL-ALL message for the purpose of closing all its connections with the serving BS. The message shall be transmitted on the basic CID.

| Syntax | Size | Notes |
|---|---|---|
| DEL-ALL_Message_Format() { | | |
| **Management Message Type = ?** | 8 bits | |
| **TLV Encoded Information** | Variable | TLV specific |
| } | | |

Table 11: DEL-ALL message format

A MSS shall generate DEL-ALL messages in the format shown in Table 11. If Privacy is enabled, the DEL-ALL message shall include the following TLV value,

**HMAC Tuple** (see 11.4.10 in IEEE 802.16-2001) – The HMAC Tuple Attribute contains a keyed Message digest (to authenticate the sender).

## *Fast UL ranging Information Element*

A Fast_UL_ranging_IE may be placed in the UL-MAP message by a BS to provide a non-contention based initial-ranging opportunity. The Fast_UL_ranging_IE shall be placed in the extend UIUC (extension code = ?) within a UL-MAP IE.
The format of the IE is PHY dependent as shown in Table 12.

| For SCa PHY: | | |
|---|---|---|
| **Syntax** | **Size** | **Notes** |
| Fast_UL_ranging_IE { | | |
| **MAC address** | 48 bits | MSS MAC address as provided on the RNG_REQ message on initial system entry |
| **UIUC** | 4 bits | UIUC ≠ 15. A four-bit code used to define the type of uplink access and the burst type associated with that access. |
| **Offset** | 12 bits | Indicates the start time, in units of minislots, of the burst relative to the Allocation Start Time given in the UL-MAP message. The time instants indicated by offsets are the transmission times of the first symbol of the burst including preamble. |
| **Reserved** | 4 bits | |
| } | | |

| For OFDM PHY: | | |
|---|---|---|
| **Syntax** | **Size** | **Notes** |
| Fast_UL_ranging_IE { | | |
| **MAC address** | 48 bits | MSS MAC address as provided on the RNG_REQ message on initial system entry |
| **UIUC** | 4 bits | UIUC ≠ 15. UIUC ≠ 4. A four-bit code used to define the type of uplink access and the burst type associated with that access. |
| **Duration** | 12 bits | The Duration indicates the length, in units of OFDM symbols, of the allocation. The start time of the first allocation shall be the Allocation Start Time given in the UL-MAP message. |
| **Reserved** | 4 bits | |
| } | | |

| For OFDMA PHY: | | |
|---|---|---|
| **Syntax** | **Size** | **Notes** |

| Fast_UL_ranging_IE { | | |
|---|---|---|
| **MAC address** | 48 bits | MSS MAC address as provided on the RNG_REQ message on initial system entry |
| **UIUC** | 4 bits | UIUC ≠ 15. A four-bit code used to define the type of uplink access and the burst type associated with that access. |
| **OFDM Symbol offset** | 10 bits | The offset of the OFDM symbol in which the burst starts, the offset value is defined in units of OFDM symbols and is relevant to the Allocation Start Time field given in the UL-MAP message. |
| **Subchannel offset** | 6 bits | The lowest index OFDMA subchannel used for carrying the burst, starting from subchannel 0. |
| **No. OFDM Symbols** | 10 bits | The number of OFDM symbols that are used to carry the UL Burst |
| **No. Subchannels** | 6 bits | The number OFDMA subchannels with subsequent indexes, used to carry the burst. |
| **Reserved** | 4 bits | |
| **CID** | 16 bits | MSS basic CID |
| } | | |

Table 12: Fast_UL_ranging_IE format

### *REG-RSP TLVs for connection re-establishment*

[Add this text to the REG-RSP text in the base standard]

The following TLVs shall be included in the REG-RSP for MSS recognized by the BS through their 48-bit MAC address (provided in the RNG-REQ message) as MSS that are performing HO,

**CID_updtae** – The CID_update is a TLV value that provides a shorthand method for renewing a connection used in the previous serving BS. The TLV specifies a CID in the new serving BS that shall replace a CID used in the previous serving BS. All the service flows and parameters associated with the old CID remain unchanged. (See Table 21).

**Connection_Info –** The Connection_Info is a compound TLV value that encapsulates the **Service Flow Parameters** and the **CS Parameter Encodings** TLVs allowed on the DSA-RSP. This TLV enables the new serving BS to renew a connection used in the previous serving BS, but with different QoS settings.

## Backbone network HO procedures

[This section should contain the procedures performed on backbone to support HO such that BS from different manufacturers are interoperable. The section should address issues such as,

- Centralized HO controller and/or distributed decision
- The information that should be exchanged (Post-HO, Pre-HO and during HO)
- Information exchange model (publishing, on request, combined)
- The transport protocol to use
- Formal definition of the messages

]

### *Backbone network services*

The backbone network provides a backhaul transmission path to the BS, and may provide other services at the control plane level. Table 13 shows a list of services provided to the BS through backbone network. Some of these services may be provided by other means (highlighted).

| Service | Possible methods for providing service | Comments |
|---|---|---|
| Backhaul for traffic | - | Transport protocol is not specified |
| Provide a BS with the identity of its neighbors | 1. Get info from ASA server<br>2. Configuration (network management) | Options (1) and (2) are really the same, the only difference is where the configuration is done |
| Provide a BS with the identity of the ASA server | 1. ASA server publishes its presence<br>2. Configuration (network management) | Message format and transport protocol need to be specified for interoperability |
| Advertise the fact that a certain MSS has registered with a certain BS | 1. BS notifies ASA server<br>2. BS notifies neighbor BS | Message format and transport protocol need to be specified for interoperability |
| Provide a BS information about a certain MSS | 1. ASA server provides information<br>2. Serving BS provides information (or network management if serving BS cannot be found) | Message format and transport protocol need to be specified for interoperability |
| Information exchange during HO | 1. ASA server is in the middle<br>2. BS to BS direct exchange | Message format and transport protocol need to be specified for interoperability |

Table 13: Backbone network services

As evident from Table 13, it is possible to exchange information between BS directly or through the ASA server. In that respect the protocol used for information exchange on the backbone can regard the ASA server as another BS, and therefore no special message will be required with regards to the ASA server.

## *Backbone network communication primitives*

The primitives described in this section may be used for communication with peer BS or with an ASA server through the backbone. [Current text assumes that the identity of neighbor BS and of the ASA server are available to each BS through configuration].

### I-am-host-of message

This message is sent by a BS to notify other BS (or the ASA server) that a certain MSS is registered with it. The message shall be sent upon MSS registration, and periodically (TBD period). The message might trigger a neighbor BS to request more information on the MSS (either directly from the sender BS, or from the ASA server). The message contains the following information,

| Field | Size | Notes |
|---|---|---|
| **Message Type = ?** | 8-bit | |
| **Sender BS-ID** | 48-bit | Base station unique identifier (Same number as that broadcasted on the DL-MAP message) |
| **Target BS-ID** | 48-bit | Base station unique identifier (Same number as that broadcasted on the DL-MAP message) |
| **Time Stamp** | 32-bit | Number of milliseconds since midnight GMT (set to 0xffffffff to ignore) |
| **Num Records** | 16-bit | Number of MSS identity records |
| For (j=0; j<Num Records; j++) { | | |
| **MSS unique identifier** | 48-bit | 48-bit unique identifier used by MSS on initial network entry |
| } | | |
| **Security field** | TBD | A means to authenticate this message |
| **CRC field** | 32-bit | IEEE CRC-32 |

Table 14: I-am-host-of message

## MSS-info-request message

This message may be sent from one BS to another (or to the ASA server) to request information about a MSS. Typically the message will be sent as a reaction to reception of an *I-am-host-of* message, or in cases where a MSS is trying to re-enter the network after a HO. The message contains the following information,

| Field | Size | Notes |
|---|---|---|
| **Message Type = ?** | 8-bit | |
| **Sender BS-ID** | 48-bit | Base station unique identifier (Same number as that broadcasted on the DL-MAP message) |
| **Target BS-ID** | 48-bit | Base station unique identifier (Same number as that broadcasted on the DL-MAP message) |
| **Time Stamp** | 32-bit | Number of milliseconds since midnight GMT (set to 0xffffffff to ignore) |
| **Num Records** | 16-bit | Number of SS identity records |
| For (j=0; j<Num Records; j++) { | | |
| **MSS unique identifier** | 48-bit | 48-bit unique identifier used by MSS (as provided by the MSS or by the *I-am-host-of* message) |
| } | | |
| **Security field** | TBD | A means to authenticate this message |
| **CRC field** | 32-bit | IEEE CRC-32 |

Table 15: MSS-info-request message

## MSS-info-response message

This message may be sent from one BS to another (or from the ASA server) to provide information about a MSS. Typically the message will be sent in response to a *MSS-info-request* message. The message contains the following information,

| Field | Size | Notes |
|---|---|---|
| **Message Type = ?** | 8-bit | |
| **Sender BS-ID** | 48-bit | Base station unique identifier (Same number as that broadcasted on the DL-MAP message) |
| **Target BS-ID** | 48-bit | Base station unique identifier (Same number as that broadcasted on the DL-MAP message) |
| **Time Stamp** | 32-bit | Number of milliseconds since midnight GMT (set to 0xffffffff to ignore) |
| **Num Records** | 16-bit | Number of SS identity records |
| For (j=0; j<Num Records; j++) { | | |
| **MSS unique identifier** | 48-bit | 48-bit unique identifier used by MSS (as provided by the MSS or by the *I-am-host-of* message) |
| **N_NSIE** | | Number of Network Service Information Elements |
| For (k=0; k<N_NSIE; k++) { | | |
| **Field Size** | 16-bit | Size of TLV encoded information field below |
| **TLV encoded information** | Variable | TLV information as allowed on a DSA-REQ MAC message |
| } | | |
| **N_SAIE** | | Number of Security Association Information Elements |
| For (k=0; k<N_SAIE; k++) { | | |
| **Field Size** | 16-bit | Size of TLV encoded information field below |
| **TLV encoded information** | Variable | TLV information as allowed on a PKM-xxx MAC messages |
| } | | |

| | | |
|---|---|---|
| **Field Size** | 16-bit | Size of TLV encoded information field below |
| **TLV encoded information** | Variable | TLV information as allowed on a SBC-REQ MAC message |
| } | | |
| **Security field** | TBD | A means to authenticate this message |
| **CRC field** | 32-bit | IEEE CRC-32 |

Table 16: MSS-info-response message

## HO-notification message

This message is sent by a BS to advertise a MSS intention to perform HO. The message is typically sent to all neighbor BS. The message serves to alert the neighbor BS that a HO event is going to happen. The message contains the following information,

| Field | Size | Notes |
|---|---|---|
| **Message Type = ?** | 8-bit | |
| **Sender BS-ID** | 48-bit | Base station unique identifier (Same number as that broadcasted on the DL-MAP message) |
| **Target BS-ID** | 48-bit | Base station unique identifier (Same number as that broadcasted on the DL-MAP message) |
| **Time Stamp** | 32-bit | Number of milliseconds since midnight GMT (set to 0xffffffff to ignore) |
| **Num Records** | 16-bit | Number of MSS identity records |
| For (j=0; j<Num Records; j++) { | | |
| **MSS unique identifier** | 48-bit | 48-bit unique identifier used by MSS (as provided by the MSS or by the *I-am-host-of* message) |
| **Estimated Time to HO** | 16-bit | In milliseconds, relative to the time stamp |
| } | | |
| **Security field** | TBD | A means to authenticate this message |
| **CRC field** | 32-bit | IEEE CRC-32 |

Table 17: HO-notification message

## HO-notification-response message

This message is sent from one BS to another BS, typically in response to a *HO-notification* message. The message serves to provide the BS that sent the *HO-notification* message with information about the level of service the MSS could expect if it transitions to this BS. The message contains the following information,

| Field | Size | Notes |
|---|---|---|
| **Message Type = ?** | 8-bit | |
| **Sender BS-ID** | 48-bit | Base station unique identifier (Same number as that broadcasted on the DL-MAP message) |
| **Target BS-ID** | 48-bit | Base station unique identifier (Same number as that broadcasted on the DL-MAP message) |
| **Time Stamp** | 32-bit | Number of milliseconds since midnight GMT (set to 0xffffffff to ignore) |
| **Num Records** | 16-bit | Number of MSS identity records |
| For (j=0; j<Num Records; j++) { | | |
| **MSS unique identifier** | 48-bit | 48-bit unique identifier used by MSS (as provided by the MSS or by the *I-am-host-of* message) |
| **QoS Estimate** | 8-bit | TBD |
| } | | |
| **Security field** | TBD | A means to authenticate this message |

| | | |
|---|---|---|
| CRC field | 32-bit | IEEE CRC-32 |

Table 18: HO-notification message

### *Backbone network communication protocol*

[The BS communicate through the backbone to perform the HO. Therefore, to ensure interoperability between BS from different manufacturers the format of this communication should be standardized (at least as a recommendation). It is proposed to use UDP as the transport protocol, and define the mapping of the messages from the previous section to it]. Resource reservation and QoS over the backbone may be left unaddressed.]

## Convergence sub-layer HO procedures

### *Supported convergence sub-layers*

[This section should discuss the types of convergence sub-layer that are supported (i.e. IPv4, IPv6, Ethernet, or others)]

### *SAP for higher layer protocols*

This section defines the services between the MAC and higher layers for supporting the HO process. In some scenarios the higher layers may use information provided by the MAC layer HO process to optimize their HO process and reduce the overall HO duration.
The information is defined as set of messages sent by the MAC layer to the higher layers, providing indication of particular events before and after MAC layer HO.

#### MSS Movement

Occurs at the MSS, indication that the MSS has registered to a new Target BS.

#### Serving BS Pre-HO

Occurs at the Serving BS, indication that a MAC layer HO of a certain MSS is about to take place.

#### Target BS Pre-Ho

Occurs at the Target BS, indication that a MAC layer HO of a certain MSS is about to take place.

#### BS Post-HO

Occurs at the Target BS or MSS, indication that a MAC layer HO between the MSS and the Target BS has been completed.

#### Serving BS

Occurs at the Serving BS, indication that MAC layer link between the Serving BS and a certain MSS has been lost.

## Setup and negotiations

[This section should discuss the following:

- Setup and negotiation procedures related to the HO
- PHY dependent parameters and associated handshake

- The model for coexistence of fixed and mobile-SS on the same air-interface instance

]

## Parameters and constants

| System | Name | Time reference | Minimum value | Default value | Maximum value |
|---|---|---|---|---|---|
| BS | NBR-ADV interval | Nominal time between transmission of NBR-ADV messages | | | 1s |
| | | | | | |
| | | | | | |
| | | | | | |

Table 19: Parameters and Constants

| Name | Type (1 byte) | Length (1 byte) | Value (Variable-length) |
|---|---|---|---|
| DCD_settings | ? | Variable | The DCD_settings is a compound TLV that encapsulates an entire DCD message (excluding the generic MAC header). All the rules and settings that apply to the DCD message apply to the contents encapsulated in this TLV. |
| UCD_settings | ? | Variable | The UCD_settings is a compound TLV value that encapsulates an entire UCD message (excluding the generic MAC header). All the rules and settings that apply to the UCD message apply to the contents encapsulated in this TLV. |

Table 20: NBR-ADV encodings

| Name | Type (1 byte) | Length (1 byte) | Value (Variable-length) |
|---|---|---|---|
| CID_update | ? | 16-bits | CID in the previous serving BS |
| | | 16-bits | Replacement CID in the current serving BS |
| Connection_Info | ? | Variable | The Connection_Info is a compound TLV value that encapsulates the **Service Flow Parameters** and the **CS Parameter Encodings** TLVs allowed on the DSA-RSP message. All the rules and settings that apply to the TLVs when used in the DSA-RSP message apply to the contents encapsulated in this TLV. |

Table 21: REG-RSP encodings

## References

[1] IEEE Std 802.16-2001 “Part 16: Air Interface for Fixed Broadband Wireless Access Systems”

[2] IEEE P802.16a/D7-2002 “Part 16: Air Interface for Fixed Broadband Wireless Access Systems – Medium Access Control Modifications and Additional Physical Layer Specifications for 2-11 GHz”

[3] K. Malki et al. “Low latency Handoffs in Mobile IPv4” Jul 2002