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Abstract	This document give an overview of handoff schemes
Purpose	Background and discussion
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Handoff Schemes Overview and

Guidelines for Handoff Procedures in 802.16

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1. Introduction

This document presents a "tutorial" on the subject of handoff, addressed by the call to contributions [1]. The intent is to bring before the study group background material on the subject and, based on that background, suggest guidelines for handoff procedures for 802.16. The documents is written from a PHY point of view, i.e. with the emphasis on mechanisms and procedures needed to support handoff, without referring to major issues like QoS , security etc.

2. Handoff – General

Handoff is a basic mobile network capability for dynamic support of terminal migration. Handoff Management is the process of initiating and ensuring a seamless and lossless handoff of a mobile terminal from the region covered by one base station to another base station.[2]

Handoffs include several procedures: measurements, decision and execution of the handoff.

Handoffs can be distinguished according to several criteria:

    a. Location of handoff function
        We distinguish here between network initiated handoff (whether mobile assisted or totally network controlled) and mobile initiated handoff (with either the mobile or the network determining the final decision)

    b. Network element involved
        Intra-cell, Inter-cell and Inter-network.

    c. Number of active connections
        Hard handoff, where only one connection exists in a given time point or soft-handoff where several connections (with the same information) are maintained simultaneously.

    d. Type of data transferred: Circuit switched or Packet switched data

Requirements from a handoff scheme are:

    - Latency:The time required to effect the handoff should be appropriate for the rate of mobility of the mobile terminal, as well as the nature of data transferred.

    - Scalability: The handoff procedure should support handoffs within the same cell, between different base stations in the same or in different networks

-     Minimal drop-off and fast recovery
-     Quality of service should be maintained or re-negotiatied after the handoff is completed.
-     Minimal additional signaling

Another aspect of mobile stations is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a station's receiver will always be powered on. [4]

3.   Handoffs in various Cellular Systems

3.1   GSM

In GSM, there are two basic types of handoffs.
1. Internal Handoff:
  (a) Intra-Cell handoff: In intra-cell handoffs, a call is transferred from one channel to another within the same cell.
  (b) Inter-Cell handoff: In inter-cell handoffs, a call is transferred from one cell to another, both of which are under the control of the same Base Station Controller (BSC).
2. External Handoff:
  (a) Intra-MSC handoff: In intra-MSC handoff, the calls are transferred between different BSCs, but belonging to the same Mobile Services Switching Center (MSC).
  (b) Inter-MSC handoff: In inter-MSC handoff, the calls are transferred between different MSCs. The old MSC is usually referred to as the anchor MSC and the new MSC is referred to as the relay MSC.

Handoffs are initiated by the mobile or the MSC. The GSM mobiles use TDMA to scan the 'broadcast control channel' of up to 16 neighboring nodes and create a list of 6 best cells for handoff. The decision is based on the signal strength. The GSM uses two handoff algorithms.

1.   Minimum acceptable performance: In this algorithm, power control is given precedence over handoffs.
2.   Power Budget algorithms: In this algorithm, handoffs are initiated to maintain acceptable signal strengths and power levels.

A GSM system partitions the handoff tasks and localizes the handoff traffic with respect to the locality and the type of migration.

3.2   UMTS

3.2.1 Types and Procedures

The handoff control of the Universal Mobile Telecommunication System (UMTS) terrestrial radio access network supports different types of handoffs and handoff procedures:

1. Intra-system Handover, which can be further subdivided into:
   a. Intra-frequency HO, between cells belonging to the same WCDMA carrier
   b. Inter-frequency HO, between cells operating on different WCDMA carriers.
2. Inter-system HO between cells belonging to two different radio access technologies (e.g. UMTS and GSM/EDGE) or two different radio access modes (e.g. FDD/WCDMA and TDD/TD-CDMA)

UMTS supports both hard handoff and soft handoff procedures. For soft HO the cells are partitioned into the "Active set", which include all the cells currently participating in a soft HO connection of a terminal, and the "Neighbor Set"/ "Monitored Set" which include all cells currently monitored by the terminal. The mobile continuously measures serving and neighboring cells, as indicated by the Radio Network Controller (RNC) and sends the measurements to the RNC. Soft HO is decided by the RNC. This is therefore a Mobile Evaluated HO, which orders the Mobile to include or remove cells form its active set. In case the handoff is to be made to a different RNC, and soft HO cannot be executed or not allowed, intra-frequency hard HO is preformed. This procedure is also a Mobile Evaluated HO.

Inter-frequency handover is a handover between different WCDMA carriers. It can be performed when two cells use different carriers, and it is also useful for a multi-layered (multi-tier) system. Inter-frequency HO is a network evaluated HO. When a mobile station is located where an Inter-frequency HO is possible and needed, the RNC commands the mobile to perform inter-frequency measurements and to report the results periodically. The HO decision is made at the RNC.

Inter-system HO is a necessary feature to support upgrade of 2G systems to UMTS and also to support the different UMTS mode. Obviously the mobile station has to support both modes. The Inter-System HO is Network Evaluated; the mobile terminal must also support the necessary measurements.

Inter-frequency and inter-system measurements require the mobile terminal measuring on a different frequency. If another receiver is to be avoided, this measurement can be done by stopping the normal transmission and reception for a certain period allowing the mobile terminal to measure on the other frequency. To achieve this gap without losing any data the data sent can be compressed in time. i.e. transmission and reception enter a Compressed Mode. There are three method of generating the gaps to use the compressed mode:

- Reducing the data rate used in the upper layers
- Reducing the symbol rate used in the physical layer
- Spreading factor splitting.

The standards allow CM to be applied in one direction only or in both directions simultaneously.

3.2.2 Base Station and Mobile Station Capabilities

In order to support handoffs the Mobile Station has to:

1. Monitor at least 32 cells on the same WCDMA carrier
2. Monitor at least 32 cells in all on two WCDMA carriers in addition to the serving cell's frequency
3. Support a maximum of 32 inter-system neighbors. A list for each neighboring system is required.

A broadcast channel is used by the BS to broadcast an initial neighbor list. The information broadcast includes identifiers for the RNC and the neighboring cells, frequency channel number and scrambling codes for the Primary Common Pilot Channels (P-CPICH), used for measurements. If the neighboring cells belong to another systems (e.g. GSM) the information relevant to the other system cell should be sent.

In addition to that, the mobile station searches continuously for new cells on the current frequency. If a candidate is detected, the cell's broadcast channel is decoded, and the cell information is retrieved. The cell identification, together with E_c/I_0 measurements is then sent to the RNC.

In order to make a inter-frequency HO, the RNC also receives measurements made by the Base Stations, which measure the uplink Signal to Interference Ratio (SIR), and report it together with the downlink transmission power and the SIR target used at that channel. The mobile station measurements of the same and of other frequencies are done according to the HO mode, and under the RNC control. Reports can be made on a periodic base or on an event triggered base. Such trigger events can be that the power measured in the P-CPICH crosses a certain threshold, or goes below another threshold. Those thresholds signify whether the new cell is an eligible candidate to be included (or excluded) from the active set. The thresholds are determined according to the power of the cells in the active set and the candidates.

Measurements of the primary common pilot channels are typically filtered, using filters of 50-200 ms filter length. Those filters make it possible to smooth out fast fading fluctuations in signal strength, for mobile stations moving at about 60km/h. For slowly moving mobiles, longer filters might be required, however they might cause latency in the HO procedure.

3.3   802.11

The IEEE 802.11 standard [4] defines the concept of "association", and for that it defines:

"Mobility types
The three transition types of significance to this standard that describe the mobility of stations within a network are as follows:
a) *No-transition:*
In this type, two subclasses that are usually indistinguishable are identified:
1) Static—no motion.
2) Local movement—movement within the PHY range of the communicating STAs {Stations} [i.e., movement within a basic service area (BSA)].
b) *BSS-transition:*
This type is defined as a station movement from one BSS {basic Service Set} (in one ESS {Extended Service Set} to another BSS within the same ESS. In a QBSS {a BSS that supports QoS – an 802.11e amendment} end-to-end QoS connections are maintained, although user-detectable disruptions may occur during handover

c) *ESS-transition:*
This type is defined as station movement from a BSS in one ESS to a BSS in a different
ESS. This case is supported only in the sense that the STA may move. Maintenance of upper layer
connections cannot be guaranteed by IEEE 802.11; in fact, disruption of service is likely to occur."

802.11 defines a set of "services". The one that provides support for mobility is the re-association service:

"The additional functionality required {to support mobility} is provided by the reassociation service.
Reassociation is a DSS, {and hence not specified by the standard}
The reassociation service is invoked to "move" a current association from one AP to another. This keeps the
DS informed of the current mapping between AP and STA as the station moves from BSS to BSS within an
ESS. Reassociation also enables changing association attributes of an established association while the STA
remains associated with the same AP. Reassociation is always initiated by the mobile STA."

Thus, according to the definitions above, 802.11 is a mobile-initiated, hard handoff
procedure. Beacon frames are used by the stations for synchronization and measurements.

3.4   HIPERLAN 2

A HIPERLAN/2 network for business environment consists typically of a number of APs {Access Points}
each of them covers a certain geographic area. Together they form a radio access network with full or partial
coverage of an area of almost any size. The coverage areas may or may not overlap each other, thus
simplifying roaming of terminals inside the radio access network. Each AP serves a number of MTs {Mobile
Terminals} which have to be associated to it. In the case where the quality of the radio link degrades to an
unacceptable level, the terminal may move to another AP by performing a handover. [5]

While the PHY layer of HIPERLAN 2 is identical to IEEE 802.11a, the Data Link Control
Layer (DLC) differs from that of 802.11, as it is centrally controlled, by a Central
Controller (CC), which is active both in Centralized mode, where communication is
controlled by and routed via an Access Point (AP), and in Direct Mode, where one of the
stations serves as a CC.

HL2 supports a number of functions; the following are related to mobility support and
handover: [6]

MT absence function: The MT may want to scan for a different frequency channel in order to find out
whether it shall perform a handover and to which new AP/CC it shall change. This function is triggered by
the MT.

Handover: The handover function will be restricted to business and public applications and will not be
supported in home networks in the first phase. The RRC {Radio Resource Controller} will decide when to
perform a handover and support its execution.

HL2 provides a set of capabilities to support the various functions, among them:
1) Association of wireless terminals in a logically distinct access subnetwork.
2) Informing the core network that hosts an access subnetwork of the changes in the population of associated
wireless terminals.
3) Monitoring of radio conditions as basis for handover between access sub-networks and for informing user
and hosting core network of the prevailing radio/traffic conditions.

NOTE: This capability is required to support Terminal initiated handover between access sub-networks without loss of connection and with limited loss of Quality of Service.
4) Support for Battery Power Conservation.

In addition, HL2 defines the following support of mobility:
HIPERLAN/2 shall support:
1) Roaming between access networks (with connection release and (re) set-up).
2) Continuous service while in motion within the contiguous area covered by the access network connected to a given switch or router.

The rate of movement to be supported is:
1) 10 m/s linear;
2) 180 deg/sec rotation.

However, link conditions and handover procedures may cause cells or packets to be lost or delayed beyond their intended delivery time. In the latter case HIPERLAN/2 may discard such data units. Recovery of this kind of error condition is outside the scope of HIPERLAN/2 and belongs to the higher layers of the protocol stack and/or application level recovery mechanisms.

4.   Handoff Using Mobile IP

As 802.16 is basically designed to support the IP environment it is important to be familiar with mobility solutions in that environment, which include (as candidates for the IETF:

- Mobile IP for the present IPv4 and the coming IPv6.
- Handoff Aware Wireless Access Internet Infrastructure (HAWAII)
- Cellular IP (CIP)
- Terminal Independent IP (TIMIP)

4.1 Mobile IP

 The Mobile IP [2,7,8], uses a packet encapsulation and redirection technique. The Mobile IP scheme is built around two components namely, the home agent and the foreign agent. The home agent is the entity that maintains a database of the current location of all the mobile terminals under its control. When a mobile node moves from away from the home region to another region, the home agent updates the database to contain the IP address of the foreign agent that is currently controlling the mobile terminal. When an IP packet is sent to the mobile node, it first reaches the home agent. The home agent encapsulates the IP packet within another IP packet with the current foreign agent as the destination. When the foreign agent receives the encapsulated IP packet, it removes the IP header information inserted by the home agent and sends the IP packet to the mobile terminal. Though the path from the mobile terminal to the fixed nodes is optimal, this scheme does not result in an optimal path from the fixed host to the mobile terminal.

IPv6 includes many features for streamlining mobility support that are missing in IP version 4 (current version), including Stateless Address Auto-configuration and Neighbor

Discovery. Mobility Support in IPv6 retains the ideas of a home network, home agent, and the use of encapsulation to deliver packets from the home network to the mobile node's current point of attachment. While discovery of a care-of address is still required, a mobile node can configure its a care-of address by using Stateless Address Auto-configuration and Neighbor Discovery. Thus, foreign agents are not required to support mobility in IPv6. In Ipv6 the "triangle effect" of Mobile IP can be overcome, by use of Source Routing.

4.2 Handoff Aware Wireless Access Internet Infrastructure

HAWAII uses a domain-based approach where the access network is divided into local domains. Each domain is structured as a hierarchy of nodes and routers forming a logical tree. A mobile terminal registers itself into an access point. The local domain (like the home agent in 4.1) has a root router to which the mobile sends the path setup message. All routers in the path provide the host-based forwarding information that gets refreshed at the root router. Old entries are removed after a time-out. When the mobile attaches to a new access point, the same process is repeated. HAWAII also keeps track of the idle users to minimize the overhead traffic by using the "paging" concept to update their location. When a mobile moves from one local domain to another, mobile IP is used and the root router assumes the role of the foreign agent. HAWAII is a better approach because it hides local mobility from the netwrork and hence results in much less overhead traffic.

4.3 Cellular IP (CIP)

Unlike Mobile IP and HAWAII are defined in layer 3, and triggered by MIP signaling after being connected to the new access point, the cellular IP uses layer 2 information about the access point, such as signal strength, to predict handover to a new access point, and the terminal triggers the procedures prior to being connected.
Like HAWAII the network is partitioned into CIP networks, each organized in an hierarchal structure. The CIP nodes maintain routing and paging caches. The routing caches are used to locate roaming mobile terminals, being updated by the IP packets transmitted by the mobile terminal. Throughout the CIP nodes, a chain of temporary cached records is created to provide information on downlink path of packets destined to the terminal. Whenever a packet arrives at the CIP node destined to the mobile terminal, that packet is sent to all interfaces mapped on the routing cache. Cached mappings must be refreshed periodically by the terminal, otherwise they expire and are deleted.
     The paging caches are maintained by paging-update packets sent to the nearest access point each time the mobile terminal moves. These records are created by mobile terminals that do not send or receive packets frequently.

4.4 Terminal Independent IP (TIMIP)

All the schemes described above make it necessary for the terminal to be mobility aware. TIMIP, presented in [9], is designed to be terminal independent and be totally

implemented within the network nodes, with no change at all made to the terminal protocol stack.

In order for the terminal to be recognized by the TIMIP network, it must be first registered offline through management procedures, and basic parameters are kept at the Access network Gateway, which basically runs "surrogate MIP" for terminals which do not have MIP capability.

At power-up the mobile terminal is recognized by the Access Point and routing tables to it are formed in all routers forming the access network. Those tables should be refreshed by messages sent by the mobile. The procedure is similar in case of "micro-mobility", when the handoff is made between access points belonging to the same access network. In this case the old path is updated as well by the access router common to the old and the new path.

In case of "macro-mobility", MIP is used, either by the mobile terminal itself, if it has the capability, or by the Access Network Gateway, which runs the protocol instead if the terminal is not capable of MIP.

5.   Requirements for handoff procedures in 802.16a

IEEE 802 is restricted by its own charter to PHY and MAC specifications. As such, system-wide support for roaming and handoff is beyond its scope. Thus, IEEE 802.16 PHY and MAC should provide means for handoff to be integrated with an external core networks. As the core network is not fully defined, 802.16smg should basically support all possible handoff procedures, such that integrating it into any network would be straightforward.

Specifically:

1. Support Network Evaluated Handoff, which includes
   a. Uplink measurements of signal strength and E_c/I_0 at the BS even for mobiles linked to other BS's
   b. Commands to the mobile to perform measurements of other base stations
   c. Switch over using either hard handoff or soft handoff
2. Support Mobile Evaluated HO, which includes
   a. Downlink measurements of signal strength and E_c/I_0, from different BS's
   b. Extracting BS information by the mobile
   c. Switch over using either hard handoff or soft handoff

Thus the PHY and MAC should include:
- Means for measurements of signals of neighboring base stations, in the same or in other frequencies
- Broadcasting of base station information
- Enabling intra-frequency handoff by providing means of simultaneous reception of two base stations, of the same frequency.
- Enabling soft and softer handoff

The MAC should also:
- Provide means for authentication and service verification for roaming and for mobile units handed over from another base station

- Provide mechanisms for inter-mode handover among the various 802.16 PHYs and their options, assuming the existence of multi-mode terminals.
- Support Mobile IP in both IPv4 and IPv6.
- Provide signal strength and other indications for Cellular IP support

6. Conclusions

In this contribution we have presented the principles of handoff procedures and described some of the procedures used in various types of systems. As 802.16 do not provide complete system specification, we have introduced the principle of handoff support, as such that would enable straightforward integration with any core network. Thus the suggested handoff procedure should include the basic function to enable both network evaluated, or mobile evaluated, mobile initiated or network initiated handoff, inter-frequency or intra-frequency handoff.

In the next meeting, procedures and PHY details for the OFDMA PHY, based on the principles outlined above shall be presented.

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