Reducing Inter-Cell Handover Events based on Cell ID Information in Multi-hop Relay Systems

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***Abstract*—To reduce handover overhead such as signaling overhead and latency, optimal handover algorithm is needed for Mobile Multi-hop Relay (MMR) systems. This article proposes a novel handover method that reduces inter-cell handover but increases intra-cell handover events, because inter-cell handover has more overhead in view of the system and gives more latency time to users rather compared to intra-cell handover. Therefore, in the proposed scheme, intra-cell handover is encouraged instead inter-cell handover using adaptive hysteresis level. Intra-cell handover performs based on higher hysteresis level than inter-cell handover. This paper also presents hierarchical relay station ID (RS ID) concept for IEEE 802.16j standard. And, additional method using MOB_NBR-ADV message is proposed in case that hierarchical ID could not be used. This proposed algorithm can decrease handover signaling overhead, latency, and unnecessary handovers called ping-pong effect as well. Also, the proposed algorithm is backward compatible with mobile station (MS). Performance analysis and simulation validate the efficiency of the proposed algorithm.**

I. Introduction

Future wireless systems are expected to provide very high data rates. Peak data rate demanding for mobile access could be around 100 Mbps and 1 Gbps in beyond 3G systems. With an existing cellular architectures, which have much lower data rates and higher bit error rates (BERs), this goal cannot be realized. Therefore, some novel cellular network architectures are being studied. Multi-hop relaying concept is a key research area as an alternate solution for beyond-3G cellular networks. Multi-hop communications are being considered for beyond-3G cellular networks in order to provide high data rate, throughput enhancement, and coverage extension. Multi-hop relaying reduces path loss as the distance between a pair of communicating stations is shortened and enables communication at higher data rate.

A great number of cells exist in Multi-hop system including RS's compared with single-hop systems, consequently, handovers frequently occur, and overhead of handovers becomes extremely high. To reduce handover overhead, fast handover algorithm is introduced in [1] based on IEEE 802.16e system. Nevertheless, overhead reduction algorithm and fast handover method for Multi-hop relaying system have not been studied yet. Hence, we propose a novel algorithm which is considered for Multi-hop relaying system and can reduce inter-cell handover occurrence which enables short handover latency which has been desired for Multi-hop relaying system.

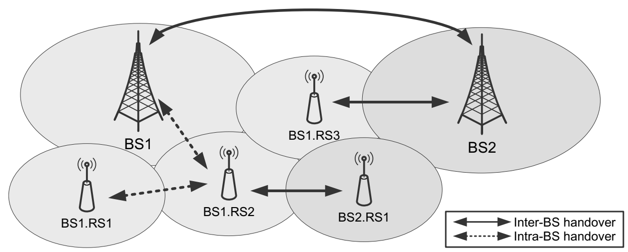

Fig. 1. Various Handover Scenarios of Multi-hop Systems

In the proposed algorithm, the major evaluation metric is not only CINR, but also cell ID information. Several cell coverages are overlapped each other in cellular systems, in other words, BS is not deployed uniformly with fixed distance each other. Therefore, when the MS changes its location with random direction and moves out from serving cell, there exist more than one candidate target BSs. Carrier to interference and noise ratio (CINR) is a major metric of handover target selection in IEEE 802.16e systems. We assume that an RS decodes and forwards data which is transmitted by BS and never transmits its own data, for that reason, the RS may be defined as a subset of the BS. And, intra-cell handover that has never been mentioned in single-hop system occurs in Multi-hop system. Therefore, we propose a handover mechanism that is applicable in Multi-hop relaying system. The definition and characteristic of inter-cell (inter-BS) handover and intra-cell (intra-BS) handover are shown in Fig. 1.

The rest of the paper is organized as follows. In Section II, we briefly explain the handover procedure of IEEE 802.16e system which is composed of network topology acquisition and actual handover process. In Section III, we propose a new handover scheme which reduces inter-cell handover event, and explain hierarchical ID concept and backup scheme. And, our proposed handover target selection algorithm is explained. In Section IV, we mathematically analyze the performance of this new algorithm. Also, we show simulation results of our proposed scheme which reduces inter-cell handover occurrence and handover latency. Finally, in Section V, we

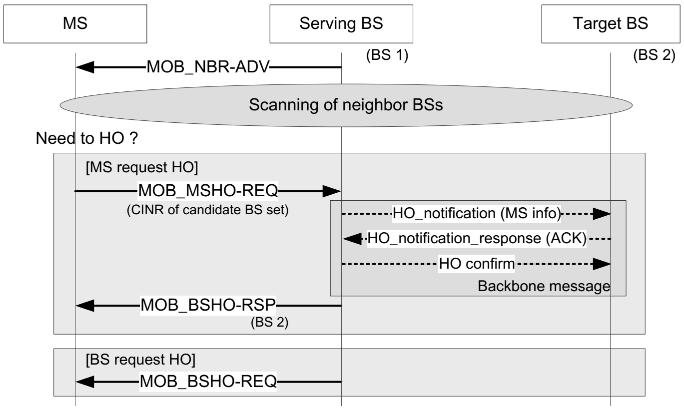

Fig. 2. Handover Triggering Process of IEEE 802.16e Systems

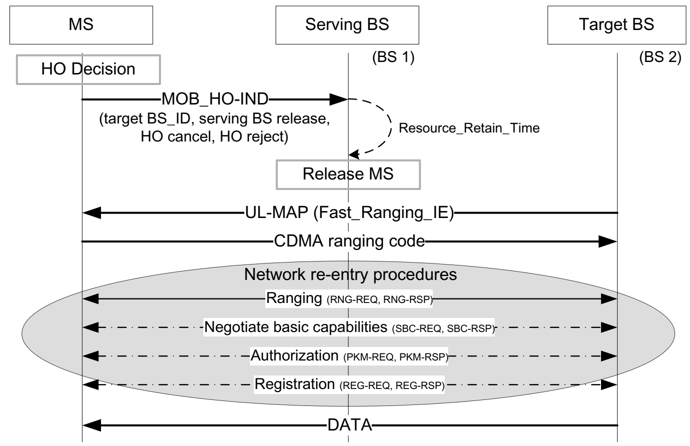

Fig. 3. Process After Handover Decision

conclude paper and further works are stated.

II. Handover Procedure of IEEE 802.16e Systems

Fig. 2 and Fig. 3 show L2 (Layer 2, Medium Access Control (MAC) layer) handover procedure of the IEEE 802.16e systems [2]. In IEEE 802.16e systems, the handover procedure is divided into two phases such as network topology acquisition and actual handover process.

A. Network Topology Acquisition

The network topology acquisition is carried out before handover request. In network topology acquisition process, BS periodically (nominal time duration is 30 seconds) broadcasts channel information of neighbor BSs using MOB_NBR-ADV (Mobile Neighbor Advertisement) message for network topology advertisement. Then, an MS measures physical channel quality of neighbor BSs by using MOB_SCN-REQ/RSP (Mobile Scanning Request/Response) messages. During this MS scanning process, the MS selects some neighbor BSs as a candidate BS for handover. Association procedure is the last step of network topology acquisition. It is an optional initial ranging procedure occurring during scanning interval. Association procedure helps to select proper target BS for potential handover.

B. Handover Process

The handover process is performed as follows. The MS should reselect the target cell in the first step of handover process. The MS may use neighbor BS information obtained from MOB_NBR-ADV message for the cell reselection. The actual handover begins with a decision to replace the serving BS. This handover triggering may originate either at the MS or the serving BS through MOB_MSHO-REQ (Mobile MS Handoff Request) or MOB_BSHO-REQ (Mobile BS Handoff Request) message as shown in Fig. 2. The MS may transmit MOB_MSHO-REQ message which includes CINR of recommend candidate BS set. And BS sends backbone messages to recommended target BSs to pre-notify impending handover of MS. After, the serving BS receives acknowledgment of pre-notifying, the serving BS confirms handover notification to the target BSs. This notification and confirmation process is expressed by dotted line in Fig. 2. After confirmation via backbone, the serving BS transmits acknowledgement for MOB_MSHO-REQ with MOB_BSHO-RSP (Mobile BS Handoff Response). Also, pre-notifying process has been done before MOB_BSHO-REQ message is sent by a serving BS when BS initiates handover.

After MS receives MOB_BSHO-RSP or MOB_BSHO-REQ messages as explained above, an MS may transmit MOB_HO-IND (Mobile Handoff Indication) message to give a final indication of handover decision to serving BS as illustrated in Fig. 3. After BS receives MOB_HO-IND message from an MS, serving BS releases the MS since resource retain time is over. Target BS transmits Fast_Ranging_IE, and the MS shall synchronize to downlink (DL) transmissions of target BS and obtain DL and uplink (UL) transmission parameters. This is the beginning of ranging process. After ranging, network re-entry procedure is performed between the MS and the target BS. The network re-entry procedure includes ranging, negotiate basic capabilities, authorization, and registration.

Actual ranging process initiated by the MS transmitting CDMA ranging code to the target station, and is completed by RNG_REQ/RSP (Ranging Request/Response) messages. The RNG_REQ message contains ID of serving BS, and the target BS may obtain MS information via backbone network. The MS performs authorization and new BS registration after all physical parameter adjustments are done successfully. The target BS requests authorization information of the MS to authorization server through backbone network. After above process, the MS is registered by new BS and then, data transmission between MS and new BS could be possible. Describing all details of the handover procedure is beyond the context of this paper. Thus, details are not stated in this paper. IEEE 802.16 and 802.16e standards give full details of the handover procedure remarkably [2].

III. Proposed Algorithm: Reducing Inter-cell Handover Occurrence

Intra-cell handover leads a simple procedure than inter-cell handover in Multi-hope system. The intra-cell handover could be handled by abbreviation of network re-entry procedure. Negotiate capabilities, authorization, and registration process are abridged for intra-cell handover, because BS manages all the intra RSs as illustrated with dash-dot line in Fig. 3. Therefore, encouraging intra-cell handover instead of inter-cell handover decreases handover signaling overhead and latency time. A hierarchical ID concept of the BS and the RS is proposed and, backup scheme is suggested in case that hierarchical ID concept could not be used.

IEEE PAR 802.16j is defining frame structure and RS protocol stack as well. For that reason, we assume frame structures and RS functionalities of Multi-hop systems, respectively [3]. The frame is constructed by subframe A and subframe B. The subframe A is used for BS, between the BS-RS link and between the BS-MS link. For an RS, between the RS-MS link, subframe B is used. An MS needs a functionality that distinguishes RS signal from BS signal, and a preamble plays an important role in this requirement. On the other hand, proposed handover scheme can be valuable regardless of frame structure or RS functionality. If the MS is able to know the difference between RS and BS signals, it does not matter either BS or RS creates Preamble, DL-MAP, and UL-MAP of the RSs. We assume RS functionality is insufficient compared to BS, and scheduling and ARQ are not mandatory items. To use this proposed algorithm, just minimum functionality such as data decoding and forwarding is required for the RSs.

A. Hierarchical BS/RS ID

MOB_NBR-ADV and MOB_MSHO-REQ message includes BS/RS ID which is used for identifying the cells. Hierarchical ID concept is needed for efficient assigning of BS/RS ID because, as mentioned above, an RS decodes and forwards data and has subordinate relationship with BS.

Fig. 4 (a) draws BS ID structure defined in IEEE 802.16 standard. BS ID consists with 48 bits in total, and most significant 24 bits are assigned for operator ID, and the rest of least significant 24 bits are used for classifying BSs. BS could be classified by 2^{24} kinds for each operator theoretically. The 48 bits of full BS ID are acquired from a MOB_NBR-ADV message. Fig. 4 (b) and (c) are suggested as a hierarchical ID in this paper. Fig. 4 (b) illustrates that total length of BS/RS ID is (48 + m) bits where the m bits are adhered for classifying RS. This may cause a trouble because the length of ID format is changed and all the ID field of legacy messages may be changed. Therefore, we recommend (c) type of hierarchical ID concept in which the ID length is the same as the IEEE 802.16e standard format. In Fig. 4 (c), legacy BSID field (24 bits) is partially used for RSID by m bits. To express BS, RSID field may be padded as zero. If RSID field is not zero, it means RSID. Each BS could include $2^m - 1$ RSs. Through this hierarchical ID, it could clarify BS or RS, and notify which BS is the superset of certain RS.

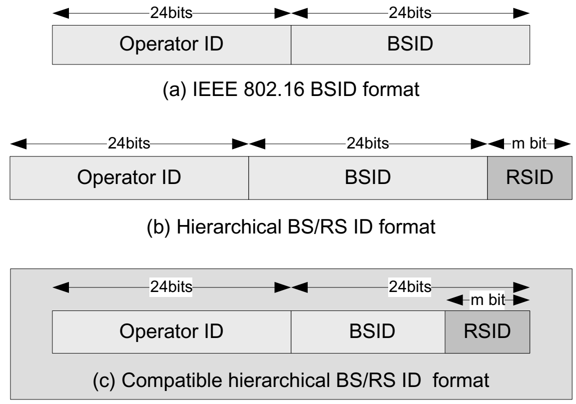

Fig. 4. Conventional & Proposed Hierarchical BS/RS ID

B. MOB_NBR-ADV messages of IEEE 802.16e

The system may re-assign all the ID of BSs and RSs to adapt hierarchical ID concept as shown in Fig. 4. Therefore, we suggest another method to acquire superset ID of certain RS. TLV encoding of MOB_NBR-ADV message is used.

TABLE I
Additional TLV encoding of MOB_NBR-ADV message

Name	Type (1 byte)	Length (1 byte)	Value (variable-length)
Neighbor RS's superset (BS) ID	tbd	6	48 bits for the Neighbor RS's superset (BS) ID parameter

TABLE I illustrates additional TLV encoding of MOB_NBR-ADV message which is proposed in this paper. This encoding is used for notifying RS's superset. Neighbors information is included in MOB_NBR-ADV message, and this TLV encoding contains cell (BS) ID additionally when an RS is the neighbor of MS. As shown in TABLE I, we notice ID information of RS's superset via TLV Encoding of MOB_NBR-ADV message, if any hierarchical ID might not be used.

C. Handover Target Selection

Fig. 5 illustrates an example of proposed handover target node selection on the assumption that cell ID is hierarchical and m is 4 bits. Fig. 5 illustrates a situation that an MS moves out of coverage BS3.RS1 which is a current serving node. The conventional algorithm will decide BS2.RS1 as a handover target whose signal strength is larger, but our proposed scheme decides BS3 as a handover target because we consider using cell ID information to decrease handover overhead.

We use deterministic incremental handover threshold value Δ_{margin}, by considering both signal strength and cell ID information with minimizing performance degradation. We give additional margin (Δ_{margin}) to the RSs within the same cell in order to reduce inter-cell handover. When the signal strength of the RSs within the same cell is denoted as S_A and the signal strength of the RSs or BSs in the other cells is

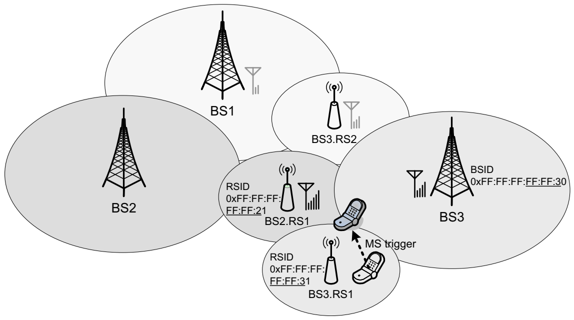

Fig. 5. Proposed Evaluation Process of Handover Target Node

denoted as S_B, $S_A + \Delta_{margin}$ is compared with S_B. In Fig. 5, we compare $S_{BS3} + \Delta_{margin}$ with $S_{BS2.RS1}$.

IV. Performance Evaluation

It is difficult to valuate the handover performance with accuracy, because handover performance is affected by various factors, such as network topology and location of entities. Therefore, we investigate the overall performance based on handover probability and latency by using a simple analytic calculation with certain assumptions. Additional simulations are accomplished to verify the effects of the proposed algorithms.

A. Inter-Cell Handover Probability

We analyze and simulate the inter-cell handover ratio gain of proposed scheme over conventional scheme.

Received signal powers from cell 1 and cell 2, S_1 and S_2 are given as follows

$$S_1 = g_1 S, \quad S_2 = g_2 S \tag{1}$$

where g_1 and g_2 are antenna gain, and S is transmitted signal from base station.

Let T be the pathloss difference in dB scale, then equation (1) can be rewritten as follows

$$10\log_{10}(\frac{S_1}{N_1}) - 10\log_{10}(\frac{S_2}{N_2}) = T \tag{2}$$

where N_1 and N_2 are noise level of each path.

When d is the distance between BS and its cell edge, accordingly, the distance between the cells is expressed by $2d$. The term x is handover distance of conventional algorithm, and y is that of the proposed scheme. Then, the ratio of x and y is deduced in the following steps.

The handover threshold of conventional and proposed schemes is expressed as follows

$$10\log_{10}(\frac{2d-x}{x})^4 = T \tag{3}$$

$$10\log_{10}(\frac{2d-y}{y})^4 = T + T' \tag{4}$$

where T is handover threshold of conventional scheme, and $T+T'$ is handover threshold of the proposed algorithm. Hence, T' is the same as Δ_{margin}. Obviously, $T+T'$ is bigger than T. Equation (3) and (4) are expressed by simplified path-loss model. In this analysis, shadowing is not considered.

$$x = \frac{2d}{1 + 10^{\frac{T}{40}}} \tag{5}$$

$$y = \frac{2d}{1 + 10^{\frac{T+T'}{40}}} \tag{6}$$

Thus, the ratio of x and y by using (5) and (6) can be expressed as

$$\frac{y}{x} = \frac{1 + 10^{\frac{T+T'}{40}}}{1 + 10^{\frac{T}{40}}} \tag{7}$$

Equation (7) derives inter-cell handover ratio gain of proposed scheme over conventional scheme where the ratio of inter-cell handover to total handover is expressed as inter-cell handover ratio.

B. Handover Latency

The handover signaling cost diminishes as a function of reduction of inter-cell handover. We verify this diminution with simple analytic calculation and simulation.

The handover delay is expressed as

$$D_{HO} = (P_{intra} \times D_{intra}) + ((1 - P_{intra}) \times D_{inter}) \tag{8}$$

where D_{HO} is handover delay, and intra-handover probability is expressed as P_{intra}. Also, D_{intra} and D_{inter} are intra-handover and inter-handover delay, respecively.

Then, the intra-cell and inter-cell handover delays are given by

$$\begin{aligned} D_{intra} &= (P_{BS1\text{–}BS1.RS} \times D_{BS1\text{–}BS1.RS}) \\ &+ ((1 - P_{BS1\text{–}BS1.RS}) \times D_{BS1.RS1\text{–}BS1.RS2}) \end{aligned} \tag{9}$$

$$\begin{aligned} D_{inter} &= (P_{BS1\text{–}BS2} \times D_{BS1\text{–}BS2}) \\ &+ (P_{BS1.RS\text{–}BS2} \times D_{BS1.RS\text{–}BS2}) \\ &+ ((1 - (P_{BS1\text{–}BS2} + P_{BS1.RS\text{–}BS2})) \times D_{BS1.RS\text{–}BS2.RS}) \end{aligned} \tag{10}$$

where P_{A-B} and D_{A-B} are probability and delay when handover between the A and B occurs.

The average delay of inter-cell handover may be larger than the average delay of intra-cell. Especially, authorization takes long time before the handover process.

C. Simulation Results

In order to prove the relevant conclusions and expressions, the Multi-hop relaying system is simulated with following parameters as shown in TABLE II.

Fig. 6 shows the graph of inter-cell handover ratio gain versus the incremental handover threshold (Δ_{margin}), which is described in (7). Compared with conventional scheme (when $\Delta_{margin} = 0$), inter-cell handover ratio gain is extremely higher in case of using more incremental handover threshold. However, the more incremental handover threshold increases inter-cell interference. The simulation is considering signal to

TABLE II
SIMULATION PARAMETERS

Parameters	Values
Cell layout	7 hexagonal cell
Cell radius	500 m
Number of RS (per cell)	6
RS position in cell	2/3 from BS
Number of MS	50 (per cell)
MS mobility model	Random way point model
Simulation Time	5000 $sec.$
Carrier frequency	3.7 GHz
Bandwidth	100 MHz
MS distribution in cell	Uniformly Random distribution
LOS pathloss model (BS-RS)	COST 231 Walfish-Ikegami street canyon model
NLOS pathloss model (BS-MS, RS-MS)	COST 231 Hata urban propagation model
Tx power	BS: $43dBm$, RS: $33dBm$
Tx antenna gain	BS: $18dBi$, RS: $12dBi$
Rx antenna gain	BS: $18dBi$, RS: $12dBi$
Body loss	BS: $-3dB$, RS: $-3dB$, MS: $-2dB$

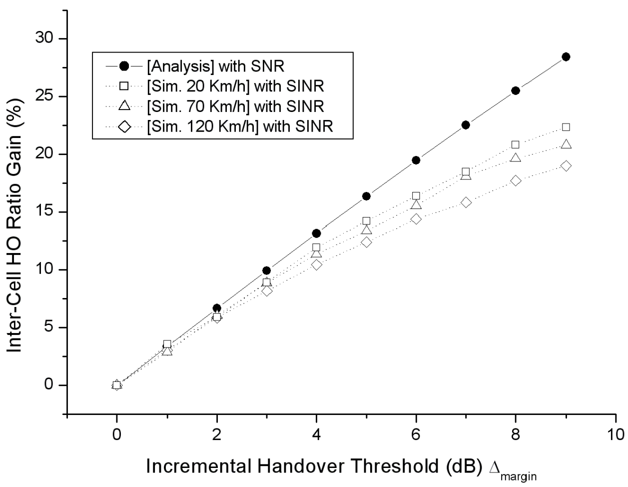

Fig. 6. Inter-Cell Handover Ratio Gain of Proposed scheme over Conventional scheme

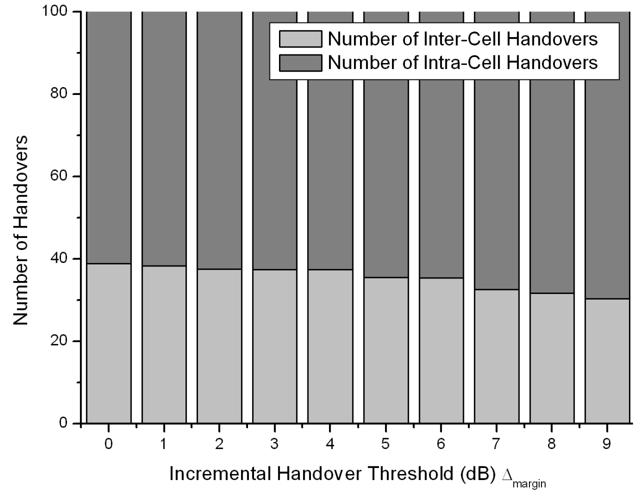

Fig. 7. Number of Inter-Cell and Intra-Cell Handovers vs. Incremental Handover Threshold

interference plus noise ratio (SINR), and the analysis is considering only signal to noise ratio (SNR). Therefore, simulation curves show differences compared with an analytic curve, and the differences become even larger since more interference is generated as the velocity of MS is becoming higher. In practice, the interference always exists, so appropriate level determination of incremental handover threshold is required for the proposed scheme. Fig. 7 shows significant reduction of inter-cell handover event for the proposed algorithm. Since the reducing of handover event is related with the reduction of handover overhead, we could expect the reduction of handover overhead accordingly.

V. CONCLUSION

In this paper, we introduced a practical handover mechanism based on Multi-hop relaying system and proposed inter-cell handover reduction algorithm which minimizes handover signaling overhead and latency. To enable low handover overhead, the proposed handover scheme uses both signaling strength and cell ID information as major metrics of handover target node selection. When applying this algorithm, we have used hierarchical ID concept and new TLV encoding of MOB_NBR-ADV message.

According to analysis and simulation results, the proposed handover algorithm performs well with respect to signaling overhead and latency. For the further work, the proper value of incremental handover threshold should be studied with minimizing SINR loss.

ACKNOWLEDGMENT

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REFERENCES

[1] Doo Hwan Lee et al., "Fast handover algorithm for IEEE 802.16e broadband wireless access system." *Wireless Pervasive Computing, 2006 1st International Symposium*, Jan. 2006.

[2] IEEE 802.16e-2005, "IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems - Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands," Dec. 7, 2005.

[3] IEEE 802.16j, IEEE 802.16's Mobile Multihop Relay (MMR) Study Group, "http://grouper.ieee.org/groups/802/16/relay/"

[4] IEEE 802.16-2004, "IEEE Standard for Local and Metropolitan Area Networks — Part 16: Air Interface for Fixed Broadband Wireless Access Systems," Oct. 1, 2004.

[5] Kyungjoo Suh, Dong-Ho Cho et al., "Open Problems in Mobilie Multi-hop Relay System," *IEEE 802.16's Relay Task Group*, IEEE C802.16mmr-05/028, Nov. 2005.

[6] H. H. Choi, O. Song, and D. H. Cho, "A seamless Handoff scheme for UMTS-WLAN Interworking," *IEEE Globecom 2004*, Vol. 3, pp. 1559-1564, Dec. 2004.

[7] Andrew J. Viterbi et al., "Soft Handoff Extends CDMA Cell Coverage and Increases Reverse Link Capacity," *IEEE Journal on Selected Areas in Communications*, Vol. 12, No. 8, pp. 1281-1288, Oct. 1994.

[8] J. Nicholas Leneman et al., "Cooperative Diversity in Wireless Networks: Low-Complexity Protocols and Outage Behavior," *IEEE Trans. Inform. Theory*, Vol. 50, No. 12, pp. 3062-3080, Dec. 2004.