Spectral Efficiency Evaluation of Downlink Mobile Multi-hop Relay Systems Employing Macro Diversity Handover Technique

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Summary

IEEE 802.16j is an amendment to the IEEE 802.16 broadband wireless access standard to enable the operation of multi-hop relay stations (RS). It aims to enhance the coverage, per user throughput and system capacity of IEEE 802.16e. There are three handover techniques supported within the IEEE 802.16e and IEEE 802.16j – Hard Handover (HHO), Fast Base Station Switching (FBSS) and Macro Diversity Handover (MDHO). This paper presents evaluations and comparisons over the performance of these handover techniques. The effect of the mobile station speed on the handover techniques' performance is also studied. The performance metric is the overall average downlink spectral efficiency which depends on the downlink carrier to interference and noise ratio (CINR). Results show that MDHO outperforms FBSS and HHO. Furthermore, as the MS speed increases, the FBSS is slightly better than HHO.

Key words:
Handover, Spectral Efficiency, Multi-hop relay, IEEE 802.16e, IEEE 802.16j.

1. Introduction

Future mobile wireless communication system is envisioned to provide very high data rates and spectral efficiency in addition to ubiquitous coverage that do not appear to be feasible with the existing cellular architecture. The achievable Carrier to Interference and Noise Ratio (CINR) decreases with an increasing link distance. Shadowing and non line-of-sight (NLOS) communications further reduce the received signal quality. Relay technology is a well-accepted economical approach to significantly enhance the link quality leading to throughput enhancement and coverage extension [1] [2] [3].

Handover is needed in multi-hop relay systems to support mobility. The main target of handover is to provide the continuous connection when a MS migrates from the air-interface of one BS to another air-interface provided by another BS. The trigger parameters were maintained from previous system because handover is determined by large scale fading [4]. There are three handover methods supported within the IEEE 802.16e and IEEE 802.16j – Hard Handover (HHO), Fast Base Station Switching (FBSS) and Macro Diversity Handover (MDHO). Of these, the HHO is mandatory while FBSS and MDHO are two optional modes. The WiMAX Forum has developed several techniques for optimizing hard handover within the framework of the IEEE 802.16e standard. These improvements have been developed with the goal of keeping layer 2 handover delays below 50ms [5].

A large number of cells exist in multi-hop systems including RSs 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 [6] based on IEEE 802.16e system.

In multi-hop cellular systems, cell overlapping is common due to the existence of a large number of cells. Therefore, when the MS moves out from serving cell, there exists more than one candidate target BSs. CINR is a major metric of HO target selection in IEEE 802.16e systems. Both intra-cell and inter-cell handovers occur in multi-hop systems. The intra-cell handover has never been mentioned in single-hop systems. In [7], a novel handover method that reduces inter-cell HO but increases intra-cell HO has been proposed. The aim was to reduce the HO signaling overhead and latency caused by inter-cell HO compared to intra-cell HO.

Since the wireless terminal cannot transmit and receive simultaneously at the same time and frequency, relaying requires at least two phases. In the first phase, source-to-relay communication takes place while in the second phase the relay forwards the received information to the destination [14]. It is assumed that the relays use Decode-and-forward (DF) forwarding scheme where they demodulate, decode, re-encode and forward the signals received from the source terminal during the first phase. Downlink and uplink channels are perfectly separated by Time Division Duplex (TDD). According to the design of the multi-hop enabled MAC frame, transmissions on the first and the second hop are assumed to be perfectly separated in time [8]. Perfect time and frequency synchronizations are also assumed.

This paper is organized as follows. The next section gives a brief description of the handover techniques of IEEE 802.16e. Section 3 describes the system model. Simulation results and discussion are presented in section 4, which is followed by our conclusions in section 5.

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2. Handover Types

2.1 Hard Handover (HHO)

During HHO, the MS communicates with only one BS in each time. Connection with the old BS is broken before the connection to a new BS is established. Handover is executed after the signal strength from a neighbor cell exceeds the signal strength from the current cell. This type of handover is less complex, fairly simple but it has high latency. Higher latency causes the unsuitability for services requiring low latency (such as VOIP). HHO is typically used for data services.

2.2 Macro Diversity Handover (MDHO)

When MDHO is supported, the MS and BS maintain a list of BSs that are involved in MDHO with the MS. This set is called an Active Set or Diversity Set. MS communicates with all BSs in the Active Set as shown in Fig. 1a. For downlink MDHO, two or more BSs transmit data to MS such that diversity combining can be performed at the MS. For uplink MDHO, MS transmission is received by multiple BSs where selection diversity of the information received is performed. The BS, noted as “Neighbor BS”, can receive communication which is among MS and Diversity Set BSs, but the signal strength is not sufficient to be added to the Diversity Set. The neighbor BSs are also called monitored set. The downlink CINR gain caused by MDHO compared to HHO is defined as MDHO gain.

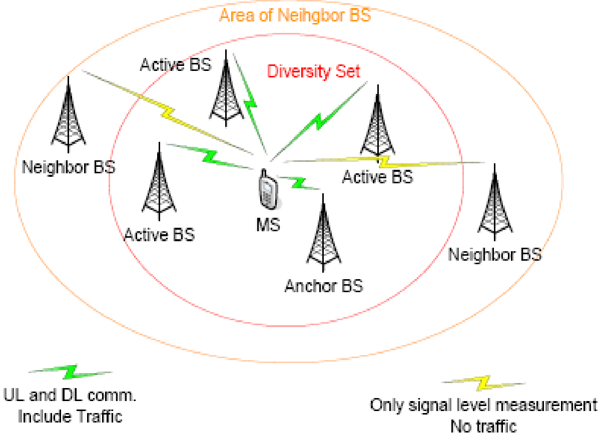

Fig. 1a Macro Diversity Handover [13]

There are some drawbacks with the use of two connections, system overhead will increase and the MS will use more network resources. MDHO is more complex than HHO but it is more stable and gives better performance and smoother transition. This kind of handover is common in UMTS [9] systems and will also be applied in IEEE 802.16e [10].

2.3 Fast Base Station Switching (FBSS)

For MS and BS that support FBSS, the Active Set is maintained by the MS and BS similarly as in MDHO. The MS continuously monitors the base stations in the Active Set and defines an “Anchor BS”. The Anchor BS is the only BS of the Diversity Set that MS communicates with for all uplink and downlink messages including management and traffic connections as shown in Fig. 1b. The Anchor BS can be changed from frame to frame depending on BS selection scheme. This means that every frame can be sent via different BS in the Diversity Set. Transition from one Anchor BS to another (i.e. BS switching) is performed without invocation of explicit HO signaling messages.

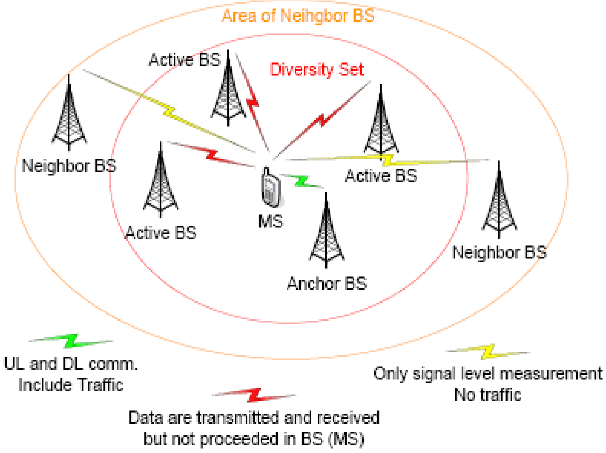

Fig. 1b Fast Base Station Switching [13]

3. Simulation Model

3.1 System Model

Performance evaluation has been carried out using a simulation tool written in MATLAB. We consider IEEE 802.16j TDD-OFDMA based two-hop cellular wireless relay network, which consists of 7 hexagonal cells. There exists one base station (BS) and six fixed relay stations (FRSs) in each cell. The BS is at the centre of the cell. Each FRS is located on the line that connects the BS to one of the six cell vertices at a 1/2 position between BS and cell boundary. The mobile stations (MS) are generated randomly in a uniform distribution in the coverage area of the centre cell. The transmit power from the BS is fixed as 43 dBm. Since the relay terminals are simpler than a BS and transmit at lower power, we assume that the transmit power from each RS is fixed as 33 dBm. The simulated topology is shown in Fig. 2.

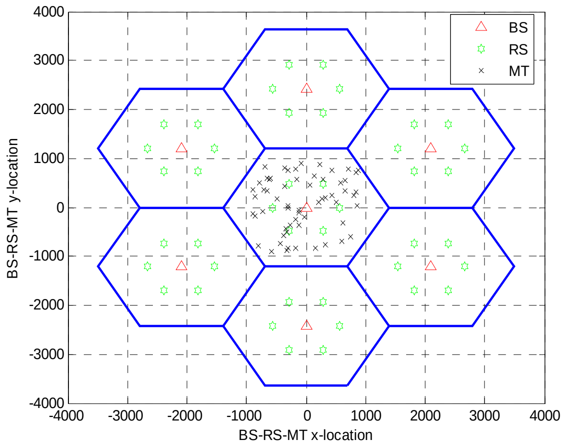

Fig. 2 The simulated topology

We consider downlink transmission in which the source is a BS and the destination is an MS. The mobile WiMAX system profile defined by WiMAX Forum is used as a reference [5] [11]. The system parameters are listed in Table 1.

Table 1: Simulation Parameters

Parameter	Value
Cell layout	7 hexagonal cells
Cell radius	1400 m
Number of RS (per cell)	6
Duplex mode	TDD
Carrier frequency	2.5 GHz
Channel bandwidth	10 MHz
Sub-channel bandwidth	262.5 kHz
Frame duration	5 ms
FFT size	1024
Antenna height	BS: 32m, RS: 15m, MS: 1.5m
Antenna gain	BS: 14dB, RS: 12dB, MS: 0dB
Antenna type	Omni-directional
Antenna number	1x1
Inter-site distance	BS-BS: 2.8km
HHO threshold	6 dB
MDHO threshold	3 dB
Active Set size	2
Lognormal shadowing	8.2 dB
Noise figure	BS/RS: 4dB, MS: 7 dB
Fast fading	Jakes spectrum

We use a flat fading channel model for BS-to-MS and RS-to-MS links with an rms delay spread of 0.231μs [16]. The Jakes fading model is used for simulating the flat fading channel. A sub-carrier spacing of 10.94 kHz is assumed. This corresponds to a 90% coherence bandwidth of 8 sub-carriers in the BS-to-MS and RS-to-MS links [17]. One sub-channel is comprised of 8 consecutive data sub-carriers over 3 OFDMA symbols. Based on these system parameters, we assume a fading channel which remains constant within a given sub-channel in a frame. A total of 60 sub-channels and hence 60 users have been simulated. Each user has been allocated one sub-channel.

We use adaptive modulation and coding (AMC) for each sub-channel and for each frame. The modulation modes that are considered in this paper are: BPSK, QPSK, 16-QAM and 64-QAM. The forward error correction (FEC) is considered in the form of convolutional coding with the following coding rates: 1/2, 2/3, 3/4 and 1 (no-coding). Each combination of the modulation and coding modes gives one AMC mode. Since AMC is used, we keep the transmit power from the RSs and the BSs constant. The spectral efficiency and received CINR are the most important performance evaluation metrics for a cellular system. The spectral efficiency and the required CINR of the supported modulation and coding schemes (MCS) in mobile WiMAX are shown in Table 2.

Table 2: Modulation and coding schemes (MCS)

No.	Modulation	Coding	Required CINR (dB)	Spectral Efficiency
MCS1	BPSK	1	6.4	1
MCS2	QPSK	1/2	9.4	1
MCS3	QPSK	3/4	11.2	1.5
MCS4	16-QAM	1/2	16.4	2
MCS5	16-QAM	3/4	18.2	3
MCS6	64-QAM	2/3	22.7	4
MCS7	64-QAM	3/4	24.4	4.5

The fixed frequency assignment scheme is adopted. The system bandwidth *F* is divided into three sub-bands equally denoted by *F= {F1, F2, F3}* and *F1=F2=F3*. Each sub-band is allocated for one relay station and reused once in the same cell. The full load frequency reuse of one is maintained for the centre users.

The MDHO and FBSS algorithm is implemented as described in 3GPP TR 25.922 [12]. It is comprised of the following conditions:

(i) If (*best_monitored_CINR* > *strongest_AS_CINR* + *MDHO_thr*) for a period *t* (*t* = time to trigger) and the Active Set is not full, the best monitored cell is added to the Active Set. This event is called Link Addition.

(ii) If (*weakest_AS_CINR* < *strongest_AS_CINR* + *MDHO_thr*) for a period *t*, then the weakest cell is removed from the *Active Set.* This event is called Link Removal.

(iii) If (*best_monitored_CINR* > *weakest_AS_CINR* + *Rep_thr*) for a period *t* and the Active Set is full, then the weakest cell is replaced by the best monitored cell. This event is called Combined Radio Link Addition and Removal.

where *best_monitored_CINR* is the strongest measured cell in the monitored set, *strongest_AS_CINR* is the strongest measured cell in the Active Set, *weakest_AS_CINR* is the weakest measured cell in the Active Set, *MDHO_thr* is the MDHO threshold, *Rep_thr* is the replacement threshold and t is a short delay between the time when the handover conditions are met and the time when the handover initialization is started.

At the beginning of the simulation, MSs are generated randomly in a uniform distribution in the coverage area of the centre cell. During the simulation, the MS moves along a direction randomly selected in each frame and communicates with an RS and/or BS based on the received signal quality and the handover technique employed. The modulation and coding scheme is adjusted on a frame-by-frame basis according to the signal quality. For each frame, the performance metrics are recorded, and at the end of simulation, the average DL CINR and spectral efficiency are calculated by dividing the recorded values by the overall simulation time.

3.2 Propagation Model

We assume the relay links between the BS and the FRSs are reliable and in line-of-sight (LOS), while the access links between BS and MS and between RS and MS are in NLOS. The LOS assumption can be practically realized by placing FRSs at a carefully selected location, such as on the roof of a building. The free space path loss model is considered for the relay link. For the access NLOS links, the modified IEEE 802.16 terrain type C path loss model is considered [15] [18]. In particular, we assume that the path loss between transmitter and receiver is of the form:

$$PL = A + 10\gamma \log_{10} (d / d_0) + \Delta PL_f + \Delta PL_h \qquad (1)$$

where d_0=100m and $d>d_0$ is the distance between the transmitter and the receiver, $A=20*\log_{10} (4\pi d_0 /\lambda)$, γ is the path loss exponent, ΔPL_f is the correction factor for frequency, ΔPL_h is the correction factor for receive antenna height, and λ is the wavelength in m.

In our simulation we use independent lognormal random variables with zero mean and a standard deviation of 8.2 dB to model the shadowing. The shadowing is assumed to be spatially uncorrelated.

Since we assume that the relay link is reliable and can support the highest rate AMC mode with negligible decoding errors, we choose the AMC mode and calculate the spectral efficiency for a given sub-channel based on the access link DL CINR.

3.3 Interference Consideration

Only the co-channel interference is taken into account in the evaluation. It is assumed that the system is fully loaded. The DL received CINR at MS is calculated by:

$$CINR_i = \frac{P_i}{\sum_{j=1, j\neq i}^{N} P_j + N_i} \qquad (2)$$

where P_i is the received signal strength from BS/RS i at MS, P_j is the received interfering signal strength from MS/RS j at MS, and N_i is the MS receiver noise. N is the maximum number of interfering BS/RS; max{N}=6 interfering BSs and max{N}=13 interfering RSs.

4. Results and Discussion

Fig. 3 illustrates the cumulative distribution function (CDF) of the overall average DL CINR for the three handover techniques at MS speed of 3 km/hr. From Fig. 3, we can see that the performance of the MDHO is the best because the user in MDHO can benefit from the maximal ratio combining performed at the MS. In addition, the FBSS and HHO handover techniques show nearly identical performance. It is obvious that the median DL CINR for a MDHO is 32.75 dB while the median DL CINR is 28.71 dB for both the FBSS and HHO.

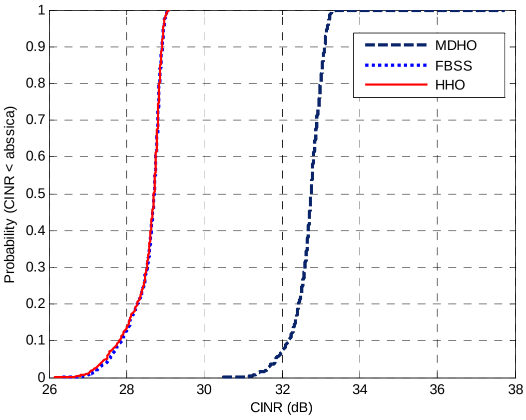

Fig. 3 CDF of average DL CINR

Fig. 4 shows the CDF of the overall average DL spectral efficiency at MS speed of 3 km/hr. It can be seen from Fig. 4 that the MDHO has higher spectral efficiency than FBSS and HHO. Furthermore, the FBSS and HHO have similar spectral efficiency. The median DL spectral efficiency for MDHO is 4.1 bps/Hz while the median DL spectral efficiency is 3.81 bps/Hz for FBSS and 3.80 bps/Hz for

HHO. In other words, 50% of the overall average DL spectral efficiency is 4.1 bps/Hz in case of using MDHO whereas 50% of the overall average DL spectral efficiency is about 3.81 bps/Hz when using FBSS and 3.80 bps/Hz when using HHO.

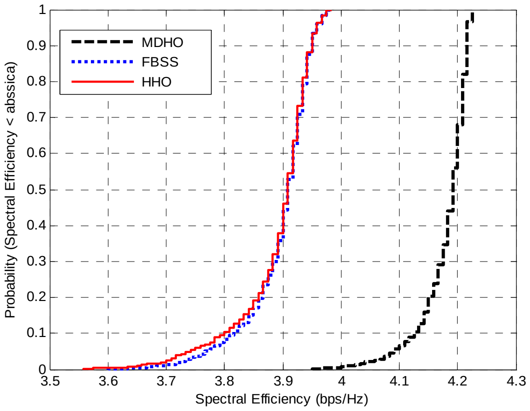

Fig. 4 CDF of average DL spectral efficiency

Fig. 5 presents the overall average DL CINR versus the MS speed for the MDHO, FBSS, and HHO handover techniques. The considered MS speeds are 3, 30, 60, 120 km/hr. As shown in Fig. 5, the MDHO has better performance than FBSS and HHO for the different MS speeds. As the MS speed increases, the DL CINR is decreased for the three handover techniques. At low MS speed, i.e. 3 km/hr, the FBSS and HHO techniques shows nearly identical performance while at higher MS speeds the FBSS shows a bit performance increment compared with HHO. For the MS speeds of 3, 30, 60 and 120 km/hr the differences between MDHO and HHO are 4.16, 2.46, 2.14 and 1.84 dB respectively. Likewise, the differences between FBSS and HHO are 0.01, 0.18, 0.2 and 0.22 dB respectively.

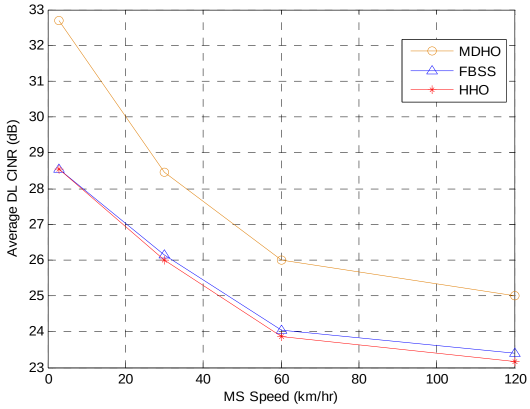

Fig. 5 Average DL CINR vs. MS speed

The effect of the MS speed on the overall average DL spectral efficiency is illustrated in the results of Fig. 6. From this figure, we can find that the spectral efficiency for the three handover techniques decreases as the MS speed increases. MDHO has higher spectral efficiency than FBSS and HHO for the considered MS speeds. Thus, the users in MDHO can receive with a higher spectral efficiency modulation and coding scheme compared to the users used FBSS or HHO. However, as the MS speed increases, FBSS shows a small performance increment compared to HHO. For the MS speeds of 3, 30, 60 and 120 km/hr the differences between MDHO and HHO are 0.29, 0.21, 0.17 and 0.15 bps/Hz respectively. Similarly, the differences between FBSS and HHO are 0.01, 0.04, 0.04 and 0.04 bps/Hz respectively.

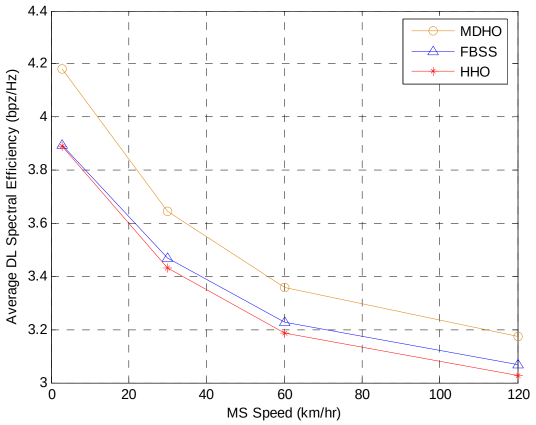

Fig. 6 Average spectral efficiency vs. MS speed

The results of Fig. 5 and 6 could be explained by noting that since the channel conditions change rapidly as the MS moves faster, this results in a lower received CINR and hence lower spectral efficiency as MS speed increases. In addition, as the channel conditions change rapidly, the MS needs to change the connection to the best serving BS/RS faster and this is what happened in FBSS handover algorithms compared to the HHO algorithms. Therefore, as the MS speed increases FBSS slightly outperforms HHO. The small difference between the FBSS and HHO is due to the fact that during the FBSS and HHO the MS connects to only one BS at each time.

Fig. 7 illustrates the Macro Diversity Handover gain at different MS speeds. The considered speeds are 3, 30, 60, and 120 km/hr. As can be seen from Fig. 7, the MDHO gain decreases as MS speed increases. The achieved MDHO gains are 4.16, 2.46, 2.14 and 1.84 dB at MS speeds of 3, 30, 60 and 120 km/hr respectively. The difference in the achieved MDHO gain between the pedestrian MS speed, i.e. 3 km/hr, and the vehicular MS speeds, i.e. 30-120 km/hr, is high and around 1.7 dB. On the other hand, the difference in the achieved MDHO gain between the vehicular MS speeds is small and around 0.3 dB.

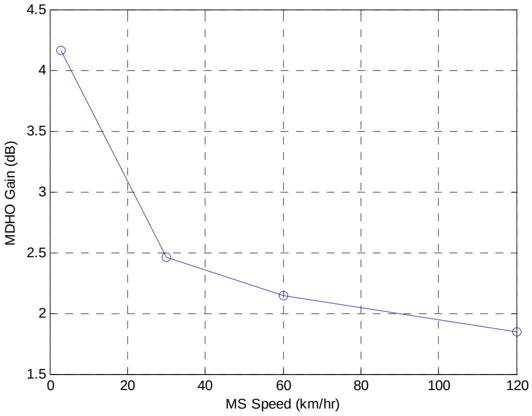

Fig. 7 MDHO gain vs. MS speed

Fig. 8 illustrates the probability of selecting an MCS with a specific spectral efficiency at MS speed of 3 km/hr. Fig. 8 reveals that due to the high DL CINR value presented in the multi-hop relay system, for the three handover techniques the probability of selecting the MCS with the highest spectral efficiency, i.e. 4.5 bps/Hz attained by 64-QAM 3/4, is high compared to the probability of selecting the other MCSs with lower spectral efficiency – up to 4 bps/Hz attained by 64-QAM 2/3 (refer to Table 2). For the 64-QAM 3/4 (MCS7), the selection probability is 83.5% for MDHO, 68% for FBSS and 68% for HHO. Hence, a larger number of MSs receive with the highest MCS, i.e. MCS7, in case of MDHO compared to users used FBSS or HHO. For a total number of 60 MSs, 50 mobile stations receive with the MCS7 in case of MDHO whereas 40 mobile stations receive with MCS7 in case of FBSS and HHO.

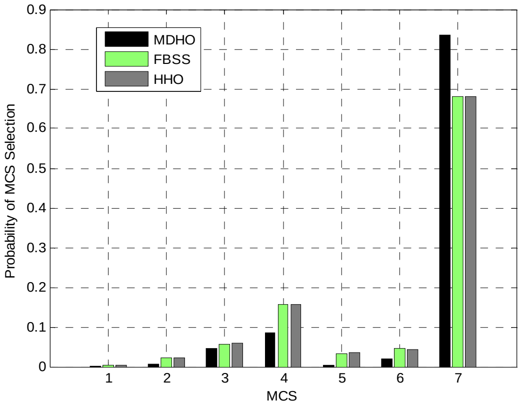

Fig. 8 Probability of different MCSs selection

Fig. 9 illustrates the effect of the MS mobility on the probability of selecting the highest spectral efficiency modulation and coding scheme, i.e. MCS7. The simulated MS speeds are 3, 30, 60 and 120 km/hr. From Fig. 9 we can find that as the MS speed increases the probability of selecting the MCS7 is decreased for the three handover techniques. For MS speeds 3, 30, 60 and 120 km/hr, the MCS7 selection probabilities in case of MDHO are 83.5%, 63.1%, 54.5% and 50.2% respectively. Similarly, the MCS7 selection probabilities for FBSS are 68%, 55.3%, 48.7% and 45.96% respectively. Likewise, the MCS7 selection probabilities in case of HHO are 68%, 54.3%, 47.7% and 44.91% respectively. The MDHO shows higher selection probabilities than FBSS and HHO for the different MS speeds. For pedestrian MS speed, FBSS has a selection probability similar to HHO. At vehicular MS speeds, on the other hand, the FBSS shows a bit higher selection probability compared to HHO.

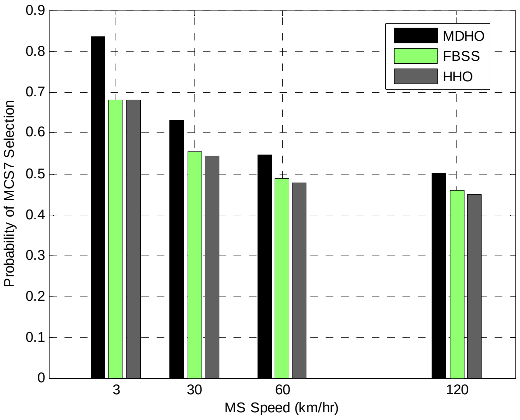

Fig. 9 Probability of MCS7 selection vs. MS speed

5. Conclusion

We have investigated the performance of the MDHO, FBSS and HHO handover techniques in IEEE 802.16j mobile multi-hop relay system. Simulation results show that MDHO has better DL CINR and spectral efficiency than FBSS and HHO handover techniques. FBSS and HHO show identical performance at low MS speed. However, as the MS speed increases, FBSS shows slightly better performance than HHO. The probability of selecting the highest spectral efficiency MCS, i.e. 64-QAM 3/4, is higher compared to the other MCSs due to the high CINR achieved in multi-hop relay system. However, this probability decreases as the MS speed increases.

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References

[1] C. Hoymann, M. Dittrich, and S. Goebbles, “Dimensioning and capacity evaluation of cellular multihop WiMAX networks,” in Proc. of IEEE Mobile WiMAX, Mar. 2007

[2] R. Pabst, B. H. Walke, D.C. Schultz, et al, “Relay-based deployment concepts for wireless and mobile broadband radio,” IEEE Communication Magazine, vol. 42, pp. 80 – 89, Sep. 2004.

[3] H. Yanikomeroglu, “Cellular multihop communications: infrastructure-based relay network architecture for 4G wireless systems,” 22nd Queen’s Biennial Symposium on Communications, Queen’s University, Kingston, Ontario, Canada, 1 – 3 June, 2004.

[4] M. Feng, H. Wang, T. Chen, “System level modeling and algorithms for a B3G system employing OFDMA,” IEE Mobility Conference 2005. The 2nd International Conference on Mobile Technology, Application and Systems. Guangzhou, China, 15-17 Nov. 2005.

[5] WiMAX Forum, “Mobile WiMAX – Part I: A technical overview and performance evaluation,” August, 2006.

[6] D. H. Lee, K. Kyamakya, J. P. Umondi, "Fast handover algorithm for IEEE 802.16e broadband wireless access system," Wireless Pervasive Computing, IEEE 2006, 1st International Symposium, Jan. 2006.

[7] J. H. park, K. Y. Han, D. H. Cho, “Reducing inter-cell handover events based on cell ID information in multi-hop relay systems,” 65th IEEE Vehicular Technology Conference, VTC Spring 2007, pp. 743-747, 22-25, April 2007

[8] C. Hoymann, M. Dittrich, S. Goebbels, “Dimensioning cellular WiMAX Part II: Multi-hop networks,” in Proc. of European Wireless 2007, Paris, France. April 2007.

[9] UMTS World, UMTS Handover. Webpage, http://www.umtsworld.com/technology/handover.htm.

[10] “Air-interface for fixed and mobile broadband wireless access systems,” IEEE 802.16e/D12, Feb. 2005.

[11] WiMAX Forum, “WiMAX Forum mobile system profile,” Nov. 2006.

[12] 3rd Generation Partnership Project, Technical Specification Group RAN, Working Group 2 (TSG RAN WG2), “Radio resource management strategies,” 3GPP TR 25.922, V3.7.0, Mar. 2002.

[13] Z. Becvar, J. Zelenka, “Implementation of handover delay timer into WiMAX,” 6th Conference on Telecommunication. Peniche, Portugal, 2007.

[14] B. Can, H. Yanikomeroglu, F. A. Onat, E. D. Carvalho and H. Yomo, “Efficient cooperative diversity schemes and radio resource allocation for IEEE 802.16j,” IEEE WCNC 2008, 31 March – 3 April 2008, Las Vegas, USA.

[15] “Multi-hop relay system evaluation methodology (Channel model and performance metrics),” IEEE 802.16j-06/013r1, Oct. 2006.

[16] D. S. Baum, J. Hansen, J. Salo, G. Del Gardo, M. Milojevic, P. Kyosti, “An interim channel model for beyond-3G systems: Extending the 3GPP spatial channel model (SCM),” in Proc. of IEEE VTC Spring, vol. 5, pp. 3132-3136, 30 May- 1 June 2005.

[17] T. S. Rappaport, “Wireless Communication Principles and Practice,” Prentice Hall Communications Engineering and Emerging Technologies Series, 2002.

[18] V. Erceg, L. J. Greenstein, S. Y. Tjandra, S. R. Parkoff, A. Gupta, B. Kulic, A. A. Julius, and R. Bianchi, “ An empirically based path loss model for wireless channels in suburban environments,” IEEE Journal on Selected Areas in communications, vol. 17, pp. 1205-1211, July 1999.

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