Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	HARQ Based ICI Cancellation for 802.16m
Date Submitted	**2008-05-09**
Source(s)	Rong-Terng Juang, Chien-Yu Kao, Jen-Yuan Hsu, Yu-Tao Hsieh, Pang-An Ting, Richard Li ITRI Hsin-Piao Lin, NTUT Pei-Kai Liao, Chih-Yuan Lin, Ciou-Ping Wu, Paul Cheng MediaTek Inc. Voice: + 886 3 5914854 E-mail: ythsieh@itri.org.tw pk.liao@mediatek.com
Re:	Call for Contributions of IEEE 802.16m_08/016r1 on the topic of “Hybrid ARQ”
Abstract	This contribution proposes a HARQ scheme to mitigate ICI effect introduced by Doppler shift and improve system performance in high mobility environment for 802.16m systems.
Purpose	Discussion and approval by the task group.
Notice	
Release	
Patent Policy	

HARQ Based ICI Cancellation for 802.16m

Rong-Terng Juang, Chien-Yu Kao, Jen-Yuan Hsu, Yu-Tao Hsieh, Pang-An Ting, Richard Li

ITRI

Hsin-Piao Lin

NTUT

Pei-Kai Liao, Chih-Yuan Lin, Ciou-Ping Wu, Paul Cheng

MediaTek

Introduction

OFDM is sensitive to carrier frequency offset. The loss of orthogonality among subcarriers causes intercarrier interference (ICI) in OFDM system and results in performance degradation. The 802.16m system requirements [1] cover the performance demand for subscriber stations at high mobility up to 350km/hr. At such high mobility, the ICI caused by Doppler spread is severe and greatly reduce throughput for link with high signal to noise power ratio.

There are many methods to reduce the ICI effect. Either use a high-complexity equalizer [2] or design a modulation scheme with the mechanism of ICI self cancellation [3]. The deficiency of the former is high complexity for ICI reduction while the deficiency of the latter is only half data efficiency remained. In the contribution, we want to design a pilot scheme for channel estimation to reduce the ICI effect without additional complexity. After getting the near ICI-free channel estimation with the proposed pilot scheme, we eliminate the ICI on data sub-carriers with successive ICI cancellation (SIC) [4]. In SIC, we need to detect data symbols and then feedback decision for the ICI cancellation. Rather than using a complex equalizer, we apply a one-tap equalizer and hard decision for data decision feedback to prevent from large number of computation in the coefficients of equalizers. For ordering of SIC, we do not need complicated ordering skills. Instead, we cancel the ICI caused by pilot sub-carriers first and then cancel the ICI caused by data sub-carriers successively by the order from the sub-carriers near pilots to those far away from pilots. In addition, we cancel the ICI with linear ICI channel model, i.e. assuming the channel variation is linear to further reduce the canceling computational complexity. Overall, the ICI cancellation can be implemented with very low complexity.

In [3], two adjacent sub-carriers are modulated to be an anti-polar pair. This document proposes a HARQ scheme for 802.16m systems to mitigate the ICI effects. An ICI cancellation coding scheme is applied to retransmitted packets by permuting symbols on adjacent subcarriers in antipodal pairs. By using the proposed HARQ scheme, high-level modulation and coding schemes can be feasible under velocities up to 350 km/hr for higher data throughput.

Proposed HARQ Based ICI Cancellation

This contribution proposes a HARQ based ICI cancellation for 802.16m in high-mobility environments. The mobility information can be obtained via many methods, such as GPS or estimation based on RSSI or CINR. For example, the MS measures CINR by the common pilots broadcasted by the BS periodically. Then, the velocity information may be estimated roughly via the variation of CINR by the MS. In case high velocity is detected, the MS feedbacks the request of the high-mobility HARQ scheme to the BS. Figure 1 displays the flow chart of the proposed HARQ retransmission scheme. A packet is first appended with the cyclic redundancy check (CRC) code, which is used for error detection. Based on the CRC decoding, if the receiver decodes the packet correctly, then the receiver sends an acknowledgement (ACK) to the transmitter as a delivery confirmation signal indicating a correct reception, otherwise the receiver sends a negative acknowledgement (NACK) and request an additional retransmission to provide the receiver a successful packet reception. Conventional HARQ scheme combines the received copies of the same packet by using maximal-ratio combining (MRC) scheme, which achieves the maximum signal-to-noise power ratio.

The frequency domain received signal of a *N*-point FFT OFDM system in a time-varying, frequency-selective multipath fading channel can be expressed as

$$Y_m = \sum_{k=0}^{N-1} X_k \sum_{l=1}^{L} \frac{1}{N} \sum_{n=0}^{N-1} h_{l,n} \exp\left[\frac{j2\pi n(k-m)}{N}\right] \exp\left(\frac{-j2\pi k\tau_l}{N}\right) + \sum_{n=0}^{N-1} z_n \exp\left(\frac{-j2\pi nm}{N}\right) \text{ for } m = 0, 1, 2, \cdots, N-1, \quad (1)$$

where X_k is the complex-valued transmitted signal for the *k*-th subcarrier, L is the number of multipath, $h_{l,n}$ is the complex-valued channel gain of the *l*-th path at *n*-th sample, τ_l represents the tap-delay of the *l*-th path, and z_n stands for an additive white Gaussian noise sample. Assume the channel variation is linear over the interval of an OFDM symbol, i.e. $h_{l,n} = \alpha_l n + \beta_l$ for $l = 1, 2, \cdots, L$, where α_l and β_l are constants. The frequency domain received signal can be rewritten as

$$Y_m = H_m X_m + \sum_{k=0, k\neq m}^{N-1} C_{k-m} H'_k X_k + Z_m, \; m = 0, 1, 2, \cdots, N-1 \quad (2)$$

where

$$H_m = \sum_{l=1}^{L} \left(\alpha_l \frac{N-1}{2} + \beta_l\right) \exp\left(\frac{-j2\pi m\tau_l}{N}\right) \quad (3)$$

$$H'_k = \sum_{l=1}^{L} \alpha_l \exp\left(\frac{-j2\pi k\tau_l}{N}\right) \quad (4)$$

$$C_{k-m} = \frac{-1}{1 - \exp\left[\frac{j2\pi(k-m)}{N}\right]} \quad (5)$$

$$Z_m = \sum_{n=0}^{N-1} z_n \exp\left(\frac{-j2\pi nm}{N}\right) \quad (6)$$

To mitigate the ICI effects, the proposed HARQ scheme permutes the data packets according the rule shown in Table 1, where $X_m = -X_{m+1}$ for $m = 0, 2, 4, \cdots, N-2$. By combining the signals, we have

$$\begin{aligned} \tilde{Y}_m &= Y_m - Y_{m+1} \\ &= \left(H_m + H_{m+1} - C_1 H'_{m+1} - C_{-1} H'_m\right) X_m + \sum_{k=0, k\neq \frac{m}{2}}^{\frac{N}{2}-1} \left[\left(C_{2k-m} - C_{2k-m-1}\right) H'_{2k} - \left(C_{2k-m+1} - C_{2k-m}\right) H'_{2k+1}\right] X_{2k} + Z_m, \end{aligned} \quad (7)$$

for $m = 0, 2, 4, \cdots, N-2$. The ICI effects can be reduced significantly [3]. To compensate the rate loss, the proposed HARQ scheme uses two antennas. Table 2 shows the permutation rule for the proposed scheme.

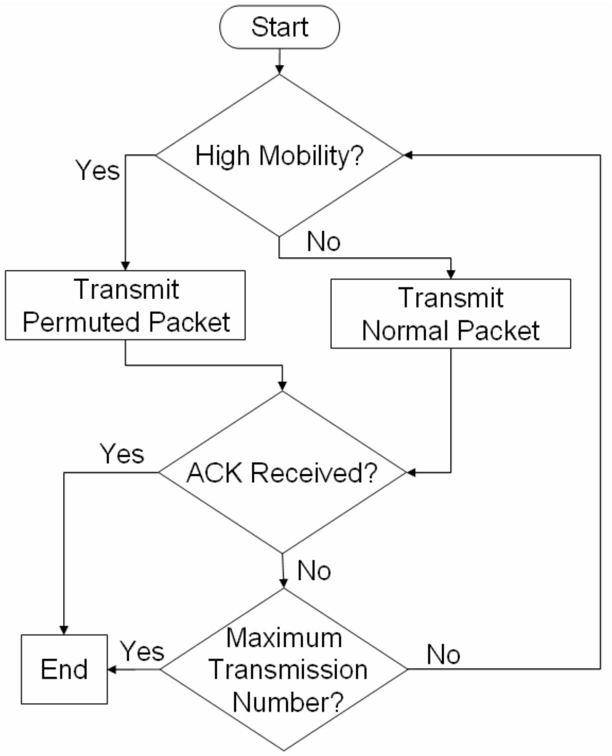

Figure 1. Flow chart of proposed HARQ scheme

Table 1. Packet Permutation Rule for the Proposed HARQ Scheme

	f_0	f_1	f_2	f_3	…	f_{N-2}	f_{N-1}
Original packet	X_0	$-X_0$	X_1	$-X_1$	…	$X_{\frac{N}{2}-1}$	$-X_{\frac{N}{2}-1}$
	$X_{\frac{N}{2}}$	$-X_{\frac{N}{2}}$	$X_{\frac{N}{2}+1}$	$-X_{\frac{N}{2}+1}$	…	X_{N-1}	$-X_{N-1}$
Retransmitted packets	X_0	$-X_0$	X_1	$-X_1$	…	$X_{\frac{N}{2}-1}$	$-X_{\frac{N}{2}-1}$
	$X_{\frac{N}{2}}$	$-X_{\frac{N}{2}}$	$X_{\frac{N}{2}+1}$	$-X_{\frac{N}{2}+1}$	…	X_{N-1}	$-X_{N-1}$

Table 2. Packet Permutation Rule for the Proposed HARQ Scheme with two Antennas

		f_0	f_1	f_2	f_3	…	f_{N-2}	f_{N-1}
Antenna 1	Original packet	X_0	$-X_0$	X_1	$-X_1$	…	$X_{\frac{N}{2}-1}$	$-X_{\frac{N}{2}-1}$
	Retransmitted packets	X_0	$-X_0$	X_1	$-X_1$	…	$X_{\frac{N}{2}-1}$	$-X_{\frac{N}{2}-1}$
Antenna 2	Original packet	$X_{\frac{N}{2}}$	$-X_{\frac{N}{2}}$	$X_{\frac{N}{2}+1}$	$-X_{\frac{N}{2}+1}$	…	X_{N-1}	$-X_{N-1}$
	Retransmitted packets	$X_{\frac{N}{2}}$	$-X_{\frac{N}{2}}$	$X_{\frac{N}{2}+1}$	$-X_{\frac{N}{2}+1}$	…	X_{N-1}	$-X_{N-1}$

Simulation Results

In the contribution, simulation results for SISO are present and simulation results for MIMO will be shown later. Tables 3 shows the parameters used in the link-level simulations. Figures 3, 4, and 5 show the performance comparisons, where 16m stands for the proposed scheme. The proposed scheme outperforms the scheme of 16e. Although, conventionally, communication systems tend to used lower-order modulation schemes in high mobility scenarios, the proposed method can be applied to high data rate applications, such as void on demand, when mobile uses are in high mobility.

Table 3. Parameters of Link-level Simulation

Carrier frequency	2.5GHz
Operating Bandwidth	11.2MHz
FFT Size	1024
Guard Interval	1024/8=128
Resource Block Size	18 sub-carrier x 6 symbol
Channel Coding	CTCs
Packet Size	48 Resource Blocks
HARQ	Chase Combining, Maximum 2 Frames retransmission delay
Channel	ITU Veh A 350km/h
User Mobility	350km/hr

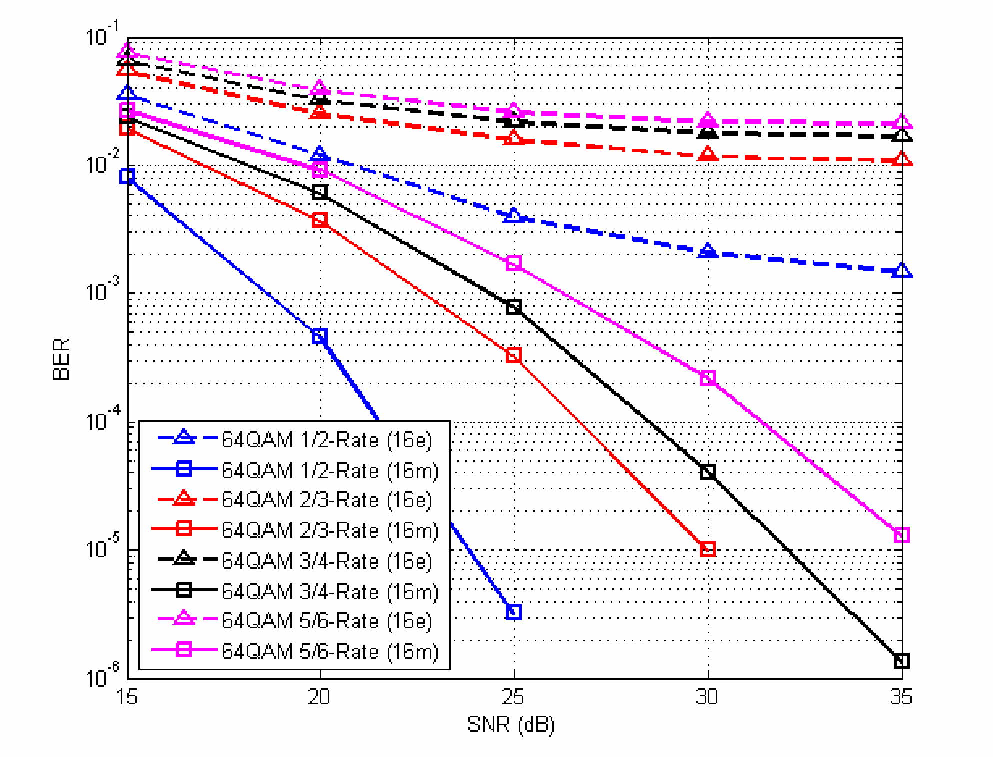

Fig. 3. BER performance comparison

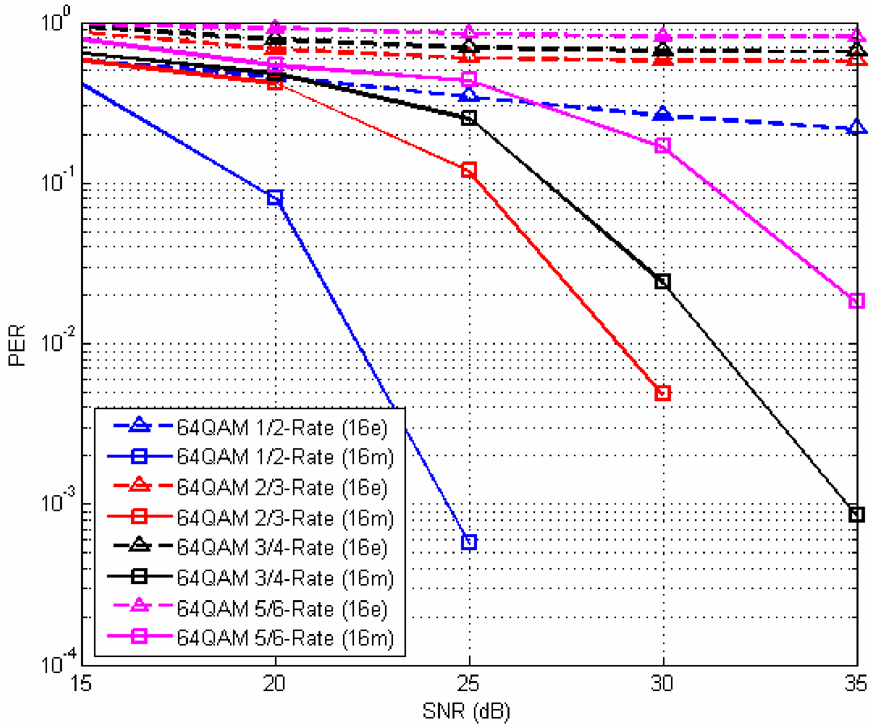

Fig. 4. PER performance comparison

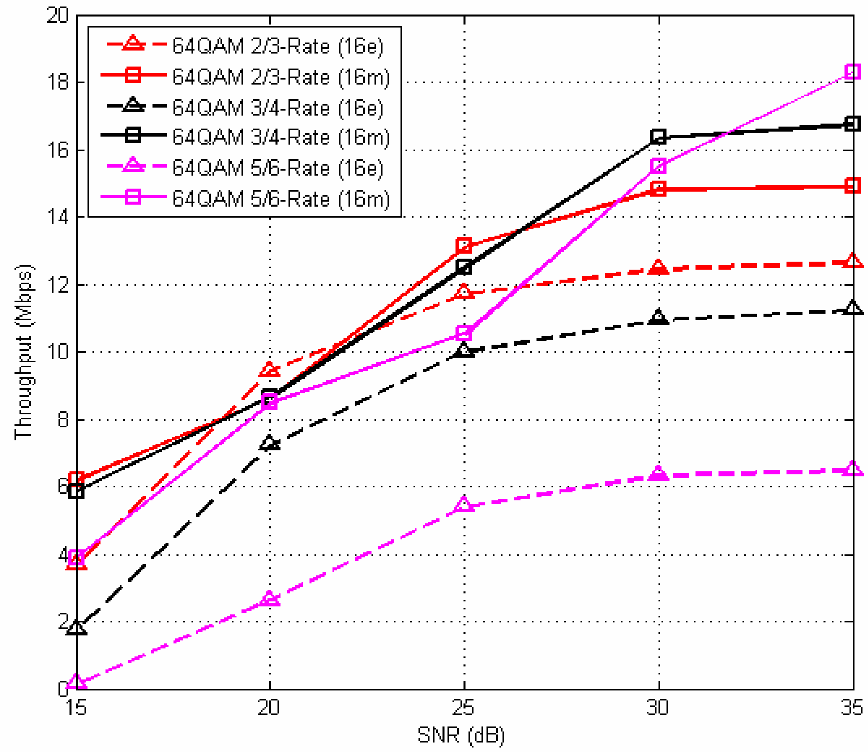

Fig. 5. Throughput performance comparison

Proposed Text

-- Start of the proposed text --

11.x Physical layer

11.x.y Hybrid ARQ

HARQ scheme with ICI cancellation can be considered for 802.16m systems. The proposed permutation rule of retransmitted packet is shown in the Table x and Table y.

Table x

	f_0	f_1	f_2	f_3	…	f_{N-2}	f_{N-1}
Original packet	X_0	$-X_0$	X_1	$-X_1$	…	$X_{\frac{N}{2}-1}$	$-X_{\frac{N}{2}-1}$
	$X_{\frac{N}{2}}$	$-X_{\frac{N}{2}}$	$X_{\frac{N}{2}+1}$	$-X_{\frac{N}{2}+1}$	…	X_{N-1}	$-X_{N-1}$
Retransmitted packets	X_0	$-X_0$	X_1	$-X_1$	…	$X_{\frac{N}{2}-1}$	$-X_{\frac{N}{2}-1}$
	$X_{\frac{N}{2}}$	$-X_{\frac{N}{2}}$	$X_{\frac{N}{2}+1}$	$-X_{\frac{N}{2}+1}$	…	X_{N-1}	$-X_{N-1}$

Table y

		f_0	f_1	f_2	f_3	…	f_{N-2}	f_{N-1}
Antenna 1	Original packet	X_0	$-X_0$	X_1	$-X_1$	…	$X_{\frac{N}{2}-1}$	$-X_{\frac{N}{2}-1}$
	Retransmitted packets	X_0	$-X_0$	X_1	$-X_1$	…	$X_{\frac{N}{2}-1}$	$-X_{\frac{N}{2}-1}$
Antenna 2	Original packet	$X_{\frac{N}{2}}$	$-X_{\frac{N}{2}}$	$X_{\frac{N}{2}+1}$	$-X_{\frac{N}{2}+1}$	…	X_{N-1}	$-X_{N-1}$
	Retransmitted packets	$X_{\frac{N}{2}}$	$-X_{\frac{N}{2}}$	$X_{\frac{N}{2}+1}$	$-X_{\frac{N}{2}+1}$	…	X_{N-1}	$-X_{N-1}$

-- End of the proposed text --

References

[1] IEEE C802.16m-07/296r1

[2] X. Cai and G. B. Giannakis, “Bounding performance and suppressing intercarrier interference in wireless mobile OFDM,” IEEE Transactions on Communications, vol. 51, no. 12, pp. 2047-2056, Dec. 2003

[3] Y. Zhao and S. G. Haggman, “Intercarrier interference self-cancellation scheme for OFDM mobile communication systems,” IEEE Transactions on Communications, vol. 49, no. 7, pp. 1185-1191, July 2001
[4] Y.S. Choi, P. J. Voltz, and F. A. Cassara, “On channel estimation and detection for multicarrier signals in fast and selective Rayleigh fading channels,” IEEE Transaction on Communications, vol. 49, pp. 1375-1387, Aug. 2001.