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Re:	IEEE 802.16m-08/005 - Call for Contributions on Project 802.16m System Description Document (SDD) shoot for “Pilot Structures as relevant to downlink MIMO”
Abstract	A pilot allocation method to reduce the intercarrier interference effect for high-mobility conditions
Purpose	To contribute the proposal of pilot design in high-mobility zone into the 802.16m SDD
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Pilot Design in High-mobility Zone for 802.16m

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Introduction

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 inter-carrier interference (ICI) caused by Doppler spread is severe and greatly reduce throughput for link with high signal to noise power ratio (SNR). For 802.16e systems, the performance, such as packet error rate (PER) or data throughputs, is bounded by the ICI even in a high SNR environment. We have presented pilot design in high-mobility zone for 802.16m systems [1]. Following previous work, we modified the cluster structure and increase pilot density to eliminate the ICI effect and improve system performance for 802.16m systems.

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 proposal applies similar scheme onto pilot sub-carriers rather than all data sub-carriers. The proposed pilot scheme allows for not only better spectral efficiency but also prominent ICI self cancellation for channel estimation and then improve the performance of further ICI cancellation on data sub-carriers. Thus, in the contribution, we propose a new clustered pilot allocation scheme for the new high-mobility zone in 802.16m to improve the system performance. In the following, we show that with this scheme, high-level modulation and coding schemes (MCS) can be feasible under velocities up to 350 km/hr for higher data throughput.

Proposed pilot allocation for SISO in the high-mobility zone

Figure 1 shows the pilot location of one cluster in the downlink PUSC in 802.16e. In contrast with Figure 1, Figure 2 illustrates the proposed pilot location of one cluster in the new downlink high-mobility zone in 802.16m. In the proposal, the structure of one cluster is two symbols by 16 sub-carriers. Focusing on the problem of ICI in a high-mobility application, we arrange the pilots to be adjacent two by two to improve the performance of channel estimation by the mechanism of ICI self cancellation. By modulating the two adjacent pilots anti-polar, we have the near ICI-free performance without canceling the ICI on each pilot. Later simulation results show that the accurate channel estimation improves the performance of ICI cancellation on data sub-carriers significantly.

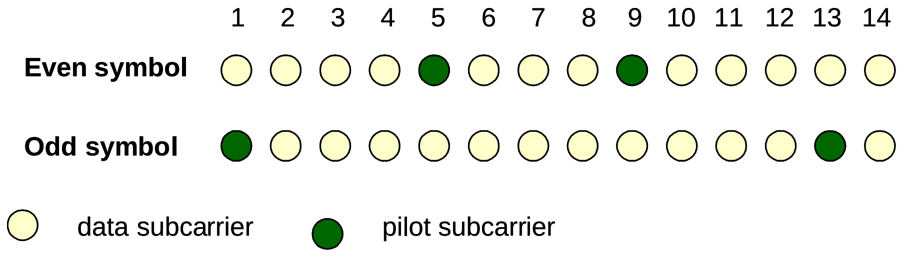

Figure 1. Cluster structure for downlink PUSC in 802.16e

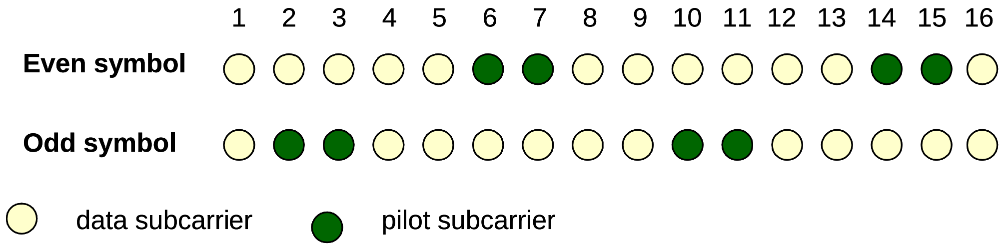

Figure 2. Proposed cluster structure for the high-mobility zone in 802.16m

Proposed pilot allocation for MIMO in the high-mobility zone

Figure 3 illustrates the pilot location of one cluster in the downlink STC PUSC using two antennas in 802.16e. Based on the principle as for SISO, Figure 4 illustrates the proposed pilot location of one cluster in the new downlink high-mobility zone using two antennas in 802.16m.

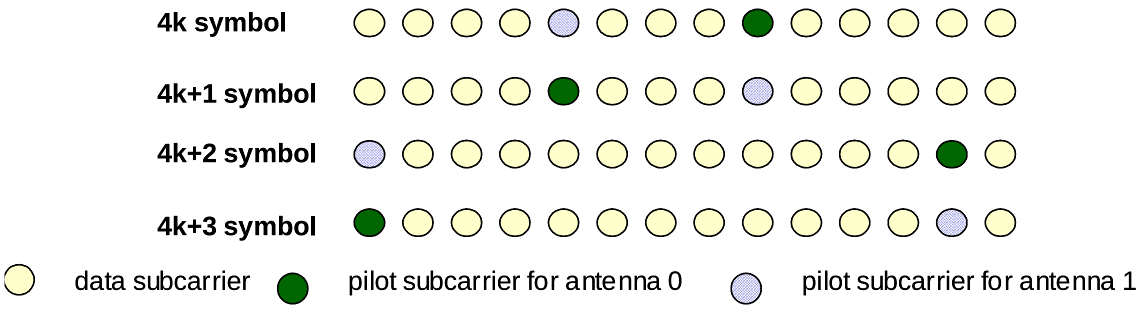

Figure 3. Cluster structure for STC PUSC using 2 antennas in 802.16e

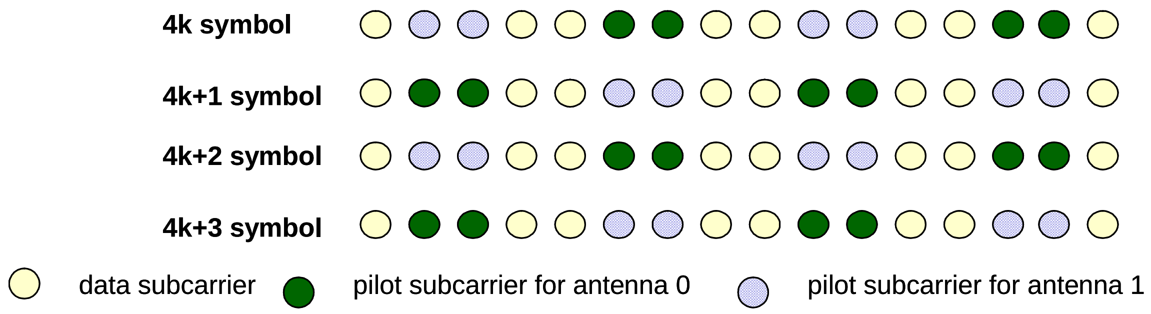

Figure 4. Proposed cluster structure for the high-mobility zone using 2 antennas in 802.16m

Proposed pilot modulation in the high-mobility zone

In 802.16e, the power of pilot sub-carriers is boosted 2.5dB over that of data sub-carriers. In addition, both pilot and data sub-carriers are modulated/re-modulated by a Pseudo Random Binary Sequence (PRBS) with the polynomial $x^{11}+x^{9}+1$. In the proposal, however, we need the two adjacent pilots with an anti-polar phase to enable the mechanism of ICI self cancellation. Therefore, in the contribution, we modulate the pilots by the same strategy as in 802.16e except that the second pilots of each adjacent pair are modulated with negative value of the first ones.

Simulation Results

In the contribution, simulation results for SISO are present and simulation results for MIMO will be shown later. In the simulations, we compare the PER and throughput performances among four schemes with different types of pilot allocation. The first is the scheme of the pilot allocation in 802.16e PUSC without ICI cancellation. The second is the scheme of the pilot allocation in 802.16e PUSC with single-iteration SIC. The linear ICI channel model is applied to reconstructing the ICI and a one-tap equalizer is utilized for hard decision to get the transmitted data symbols. Here, we notate the above ICI cancellation mechanism as "*one-tap SIC*." The third is the scheme of the proposed pilot allocation with one-tap SIC. In order to compare the proposed clustered pilot scheme and the conventional equispaced pilot scheme, we create the same cluster structure with the same number of pilots as the proposed pilot scheme but the pilots are allocated in an equal distance as shown in Figure 5. Hence, the forth is the scheme of the equal pilot allocation in Figure 5 with one-tap SIC. To sum up, the four compared schemes are as following:

Scheme 1: the pilot allocation in Figure 1 (802.16e PUSC) and no ICI cancellation

Scheme 2: the pilot allocation in Figure 1 (802.16e PUSC) and one-tap SIC

Scheme 3: the proposed pilot allocation in Figure 2 and one-tap SIC

Scheme 4: the equal pilot allocation in Figure 5 and one-tap SIC

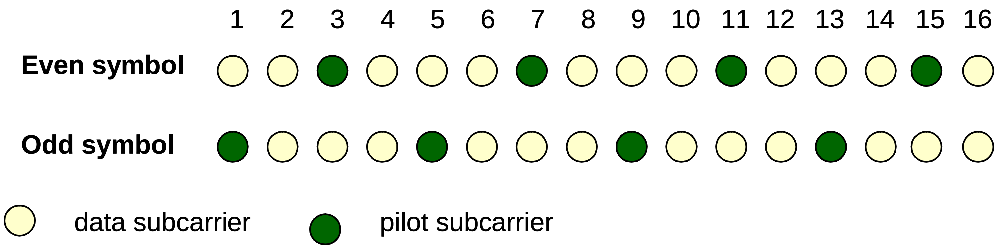

Figure 5. compared cluster structure for the high-mobility zone in 802.16m

The simulation parameters are set as in Table 1. Moreover, in order to have the same number of clusters as 802.16e, we shorten the guard band for the proposed cluster structure by 2*60 sub-carriers, i.e. the number of left and right guard sub-carriers becomes 32 and 31, respectively. In this way, the number of used sub-carriers in one OFDM symbol becomes 960 from 840. Taking it into account, we normalize the data throughput with the proposed cluster structure by the factor of 960/840.

Table 1. Simulation parameters

Carrier frequency	2.5GHz
Subcarrier spacing	10.94kHz
Channel model	ITU-VA (modified) + Jakes
FFT size (N)	1024
Guard Interval	1024/8 = 128
Permutation	PUSC
MS velocity	350 km/hr
Pilot power boosting	2.5 dB
Channel Coding	Convolutional Coding
Packet size	66 slots (22 symbols by 6 subchannels)
HARQ	Chase combining, maximum 4 retransmissions, 2-frame retransmission delay
Channel estimation	MMSE
ICI cancellation	±6 subcarriers canceling range, single iteration, linear ICI channel model

Figure 6 shows the PER comparison among the four schemes under a velocity of 350 km/hr. If take PER of 0.1 as the *goal PER*, Scheme 1 can reach the goal PER only in the MCS of 16QAM 1/2 at a SNR of 21 dB. With ICI cancellation, Scheme 2 has a slight gain over Scheme 1 but also fail to reach the goal PER in the higher-level MCS of 64QAM 1/2. Therefore, we can see that the effect of ICI cancellation is not sufficient with the pilot allocation scheme in 802.16e PUSC. Next, with the proposed pilot scheme and cluster structure, Scheme 3 can attain the goal PER even in 64QAM 2/3. By contrast, with the conventional equispaced pilot allocation, Scheme 4 can only be successful to reach the goal PER in 64QAM 1/2 at a SNR of 25 dB worse than Scheme 3 by one dB and fail to reach the goal PER in the higher-level MCS of 64QAM 2/3. Clearly, Scheme 3 with the proposed clustered pilot scheme can result in a much better performance against the ICI caused by heavy Doppler spread than the other three schemes.

Figure 7 shows the data throughput comparison among the four schemes under a velocity of 350 km/hr. Although the proposed pilot scheme leads to a higher pilot density, it also makes operation in higher-level MCS practical and thus results in higher data throughput for mobile users. For example, from Figure 7, in case of SNR equal to 30 dB, the max throughput for 802.16e PUSC with ICI cancellation (Scheme 2) is about 18Mbps in 64QAM 1/2 (but PER > 0.1) while the max throughput for the proposed scheme can reach to about 22Mbps in 64QAM 2/3 (PER < 0.1). That is, the proposed scheme can make a 22% enhancement of data throughput.

To sum up, the proposed pilot scheme not only improves the performance of PER but also lifts the data throughput. So, it can lead system to operation with high data throughput rather than just connection status in a high-mobility environment.

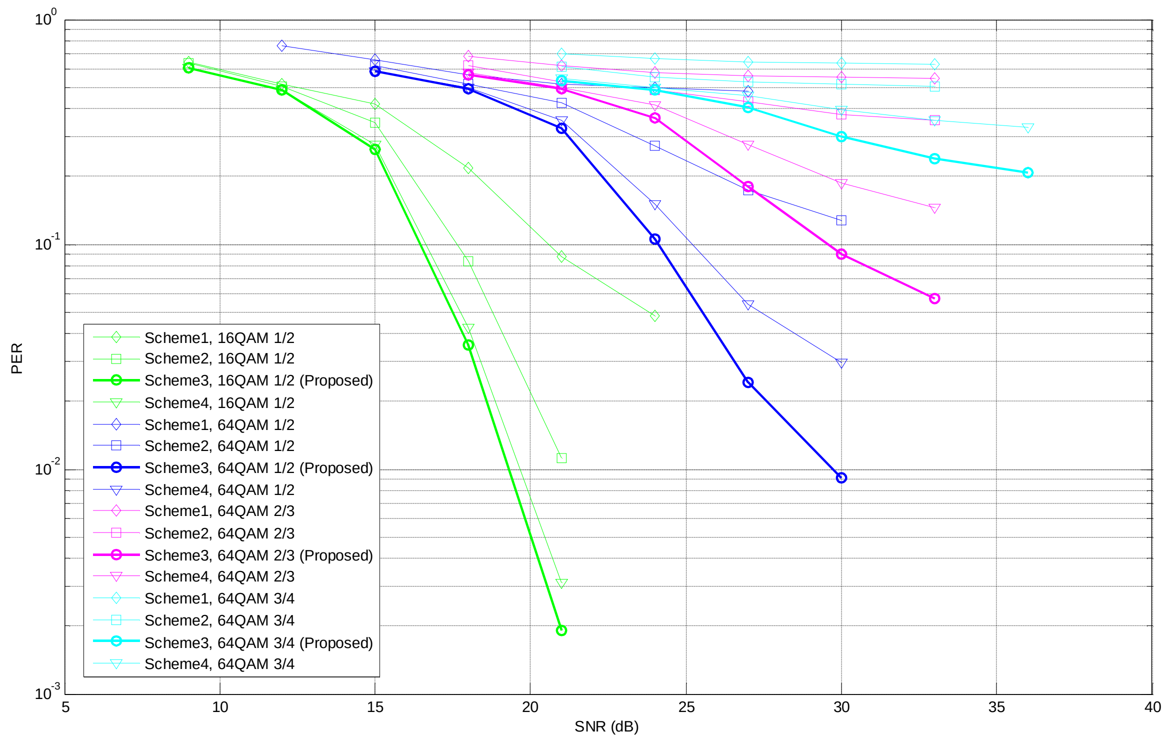

Figure 6. PER comparison among different schemes under a velocity of 350 km/hr for SISO

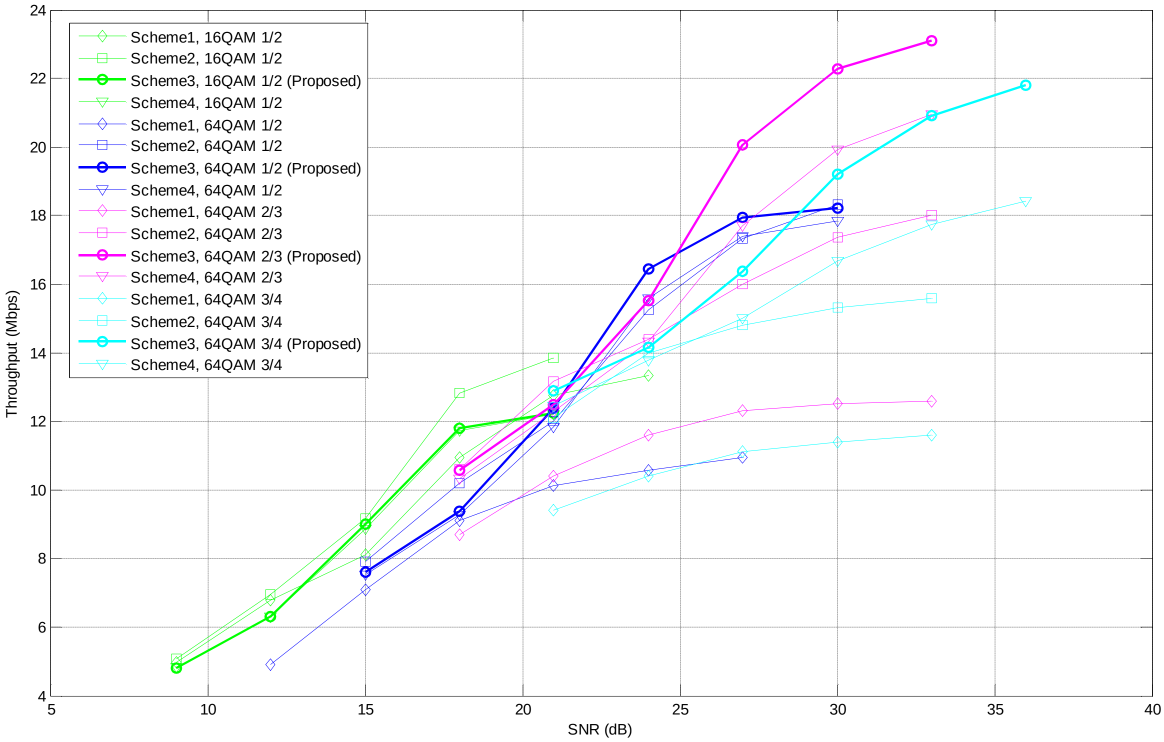

Figure 7. Single-user throughput comparison among different schemes under a velocity of 350 km/hr for SISO

Besides link-level simulations, Table 2 lists the parameters of system level simulation. Figure 8 shows the received signal power of 19 cells system-level simulation layout. Figures 9, 10, 11, and 12 plot the histograms of sector MAC throughputs for 16QAM1/2, 64QAM1/2, 64QAM2/3, and 64QAM3/4 at350Km/h, respectively. Table 3 lists the average sector throughputs. The proposed high-mobility zone design outperforms the 802.16e up to 50.73%.

Table 2 Parameters of Link-level Simulation for the Downlink

Site-to-Site distance	2.0 km
Carrier Frequency	2.5GHz
Operating Bandwidth	10MHz
BS Height	32 m
BS Tx Power	46 dBm
MS Height	1.5 m
Path Loss Model	Loss (dB) = 130.62 + 37.8log10(R), R in km
Lognormal Shadowing Deviation	8 dB
Correlation Distance for Shadowing	50 m
Mobility	350km/hr

Channel	ITU modified VA 350km/h
Frequency Reuse	3 Sectors with Frequency Reuse of 3
Interference Model	Frequency selective interference model for PUSC, no interference awareness at receiver
Scheduling	Proportional Fairness for full buffer data only [10 active users per sector, fixed control overhead of 6 symbols, 22 symbols for data, 5 partitions of 66 slots each, latency timescale 1.5s]

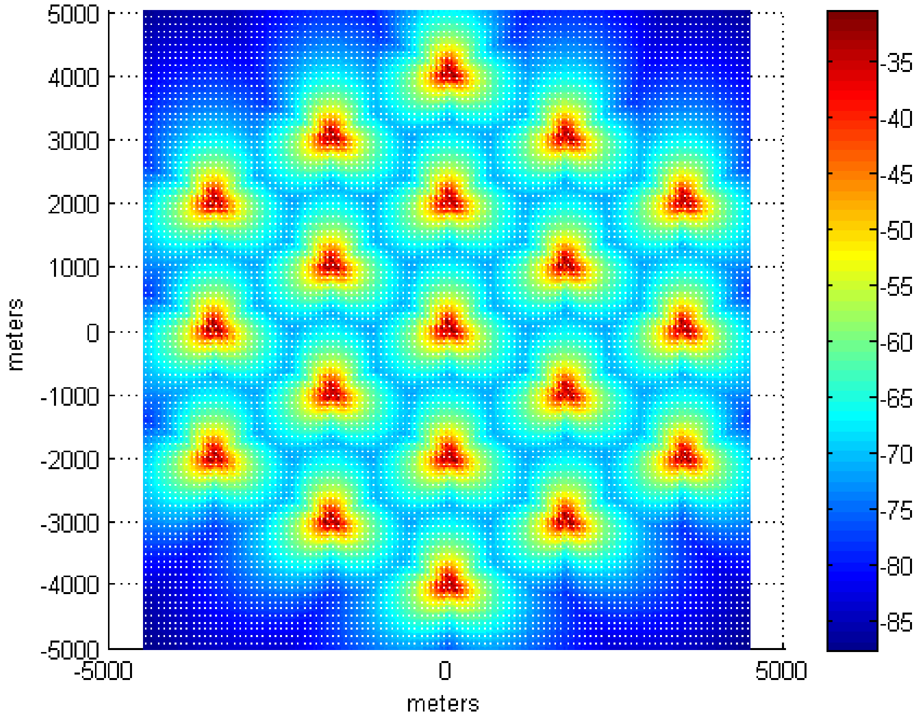

Figure 8. Received Signal Power of Multi-cell Simulation Layout

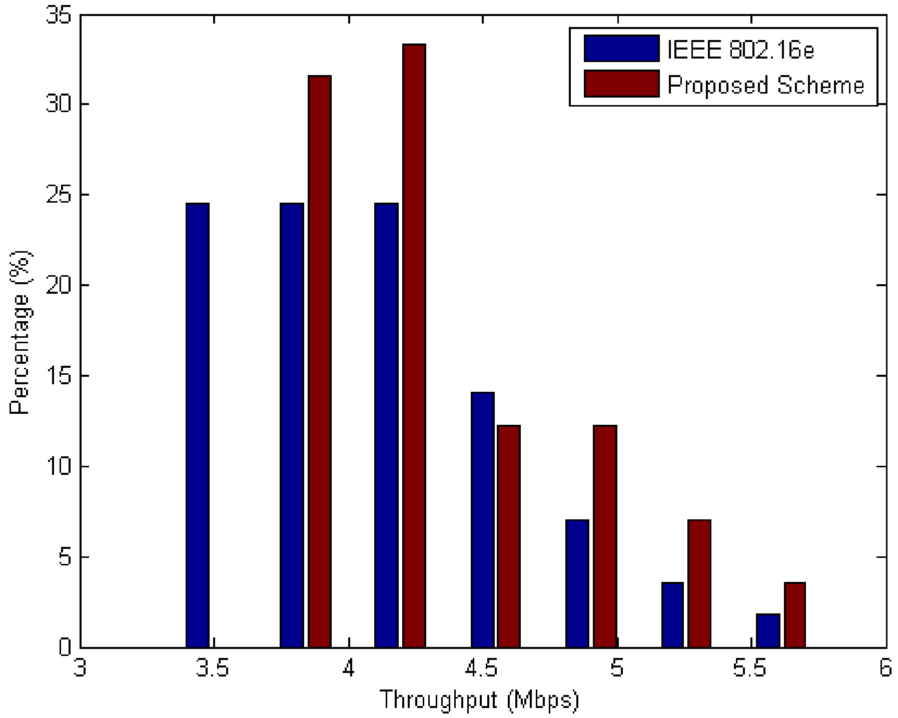

Figure 9. Histogram of Sector MAC Throughput for 16QAM1/2 at 350Km/h

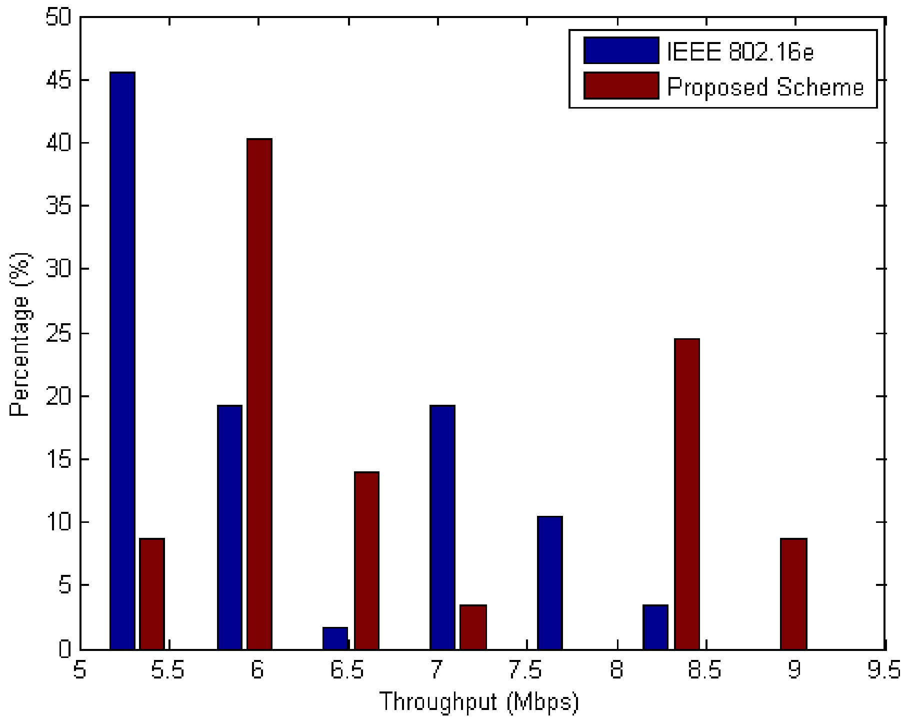

Figure 10. Histogram of Sector MAC Throughput for 64QAM1/2 at 350Km/h

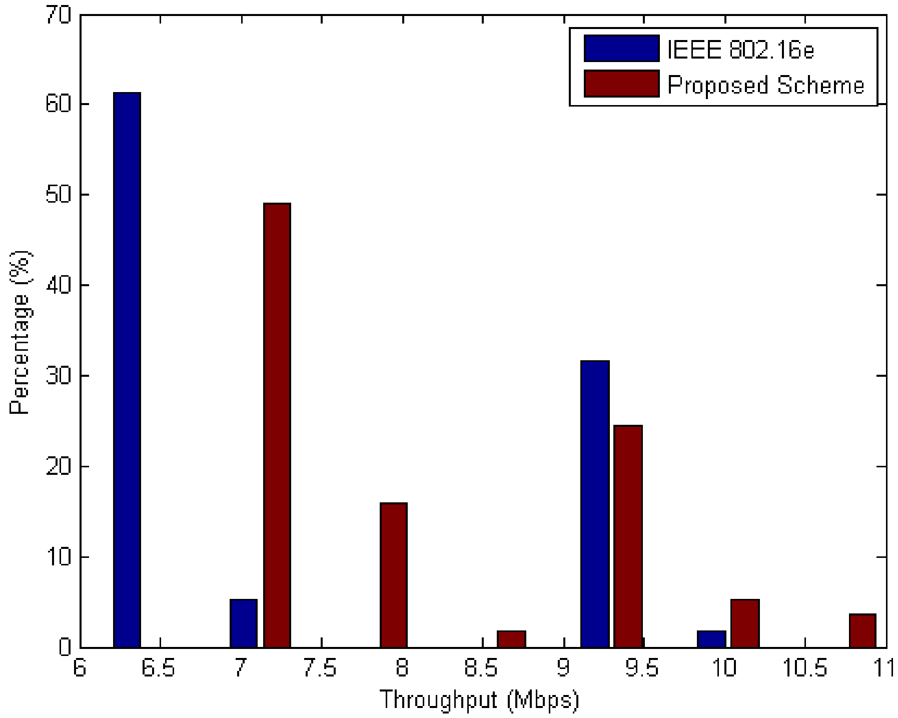

Figure 11. Histogram of Sector MAC Throughput for 64QAM2/3 at 350Km/h

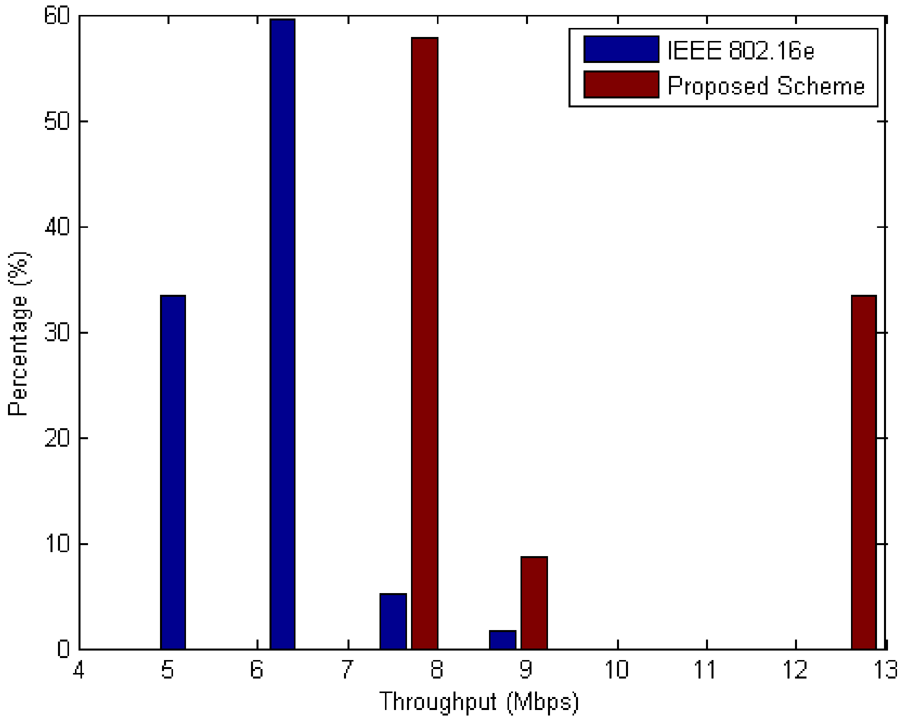

Figure 12. Histogram of Sector MAC Throughput for 64QAM3/4 at 350Km/h

Table 3. Average Sector Throughput for High-Mobility Zone (Mbps)

	Average Sector Throughput for User at 350Km/h Mobility		
	16e	Proposed Scheme	Improvement (%)
16QAM1/2	4.08	4.37	7.11
64QAM1/2	6.18	6.87	11.17
64QAM2/3	7.36	8.12	10.33
64QAM3/4	6.15	9.27	50.73

Proposed SDD Text

[Chapter] Physical Layer

………

[Section] Frame Structure

………

[Subsection] High-mobility Zone

………

[Subsection] Pilot allocation

The structure of one cluster is two symbols by 16 sub-carriers and the pilots are arranged adjacent two by two as shown in Figure XX and Figure YY for SISO and 2x2 MIMO, respectively. Moreover, the pilots are modulated by a PRBS with anti-polar phase.

[Other additions]

………

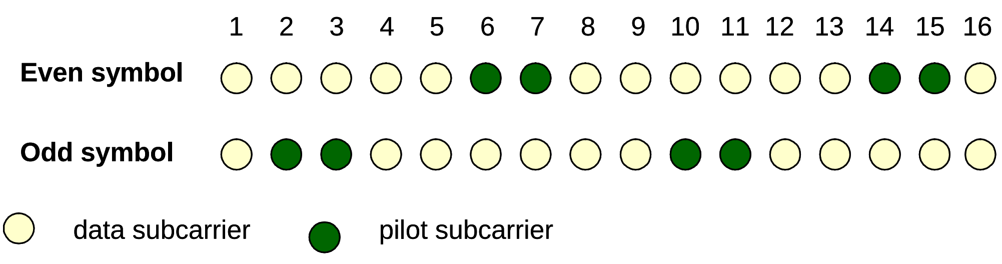

Figure XX. Proposed cluster structure for the high-mobility zone in 802.16m

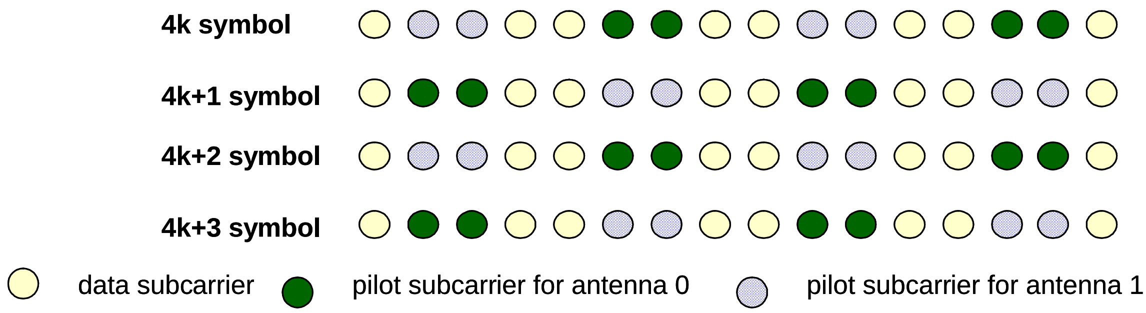

Figure YY. Proposed cluster structure for the high-mobility zone using 2 antennas in 802.16m

Reference

[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.