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Re:	802.16m-08/016r1: Call for SDD Comments and Contributions – Downlink MIMO Schemes
Abstract	This contribution proposes a MIMO broadcast scheme to be included in the 802.16m System Description Document (SDD).
Purpose	To be discussed and adopted by TGm for the 802.16m SDD.
Notice	
Release	
Patent Policy	

MIMO Broadcast for 16m E-MBS

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Introduction

Enhanced multicast broadcast service (E-MBS) is an important requirement of 16m. As stated in the 16m System Requirement Document ([1]), "IEEE 802.16m shall provide support for an enhanced multicast broadcast service (E-MBS), providing enhanced multicast and broadcast spectral efficiency, as specified in Table 14 in Section 7.5."

"Minimum performance requirements for E-MBS, expressed in terms of spectral efficiency over 95% coverage area, appear in Table 14.

Table 14–MBS minimum spectral efficiency vs. inter-site distance

Inter-site distance (km)	Min. Spectral efficiency (bps/Hz)
0.5	4
1.5	2

The following notes apply to Table 14:

1. The performance requirements apply to a wide-area multi-cell multicast broadcast single frequency network (MBSFN).
2. The specified spectral efficiencies neglect overhead due to ancillary functions (such as synchronization and common control channel) and apply to both mixed unicast-broadcast and dedicated MBS carriers, where the performance is scalable with carrier frequency bandwidth."

A single-frequency network (SFN) operation can be realized for broadcast traffic transmitted using OFDMA from multiple cells with timing errors within the cyclic prefix length. In the presence of SFN operation, the broadcast SINR can be very high particularly for smaller cells deployments.

It is expected that the 16m system would use some form of MIMO technique for unicast traffic. When multiple transmit and receive antennas and multiple transmit and receive chains are available, it becomes logical to exploit the MIMO benefits for E-MBS traffic as well. A key difference between unicast and broadcast, however, is that only open-loop MIMO techniques can be utilized for E-MBS due to absence of feedback from the MS. This includes some form of transmit diversity or open-loop spatial multiplexing of multiple streams.

This contribution provides a MIMO broadcast scheme for 16m.

Motivation for Spatial-Multiplexing for E-MBS

It is well-known that E-MBS performance is generally determined by the "outage" requirement for the cell edge users. However, the cell edge users potentially receive E-MBS signals from multiple cells. Therefore, sufficient "macro" spatial or frequency diversity is available even without any form of transmit diversity. The incremental gains due to transmit diversity for multicast/broadcast are expected to be relatively small. However, the SINR for cell edge users in a single frequency network (SFN) operation can be relatively higher, for example, 10.0dB or higher for most commonly used cell sizes. These higher SINRs for cell edge users can potentially be translated into higher data rates and capacity for E-MBS by MIMO spatial multiplexing. Note that without spatial multiplexing, the multicast/broadcast capacity will only grow logarithmically with SINR in the high SINR region.

Higher SINR in a Single-Frequency Network (SFN)

The Broadcast geometry for various site-to-site (s2s) distances is shown in Figure 1. We note that 10% Geometry point (90% broadcast coverage) is approximately 11dB, 21dB and 29 dB for site-to-site (s2s) distance of 2.0, 1.0 and 0.5Kms. These very large SINRs (geometries) indicate that spatial multiplexing can be beneficial for the E-MBS traffic.

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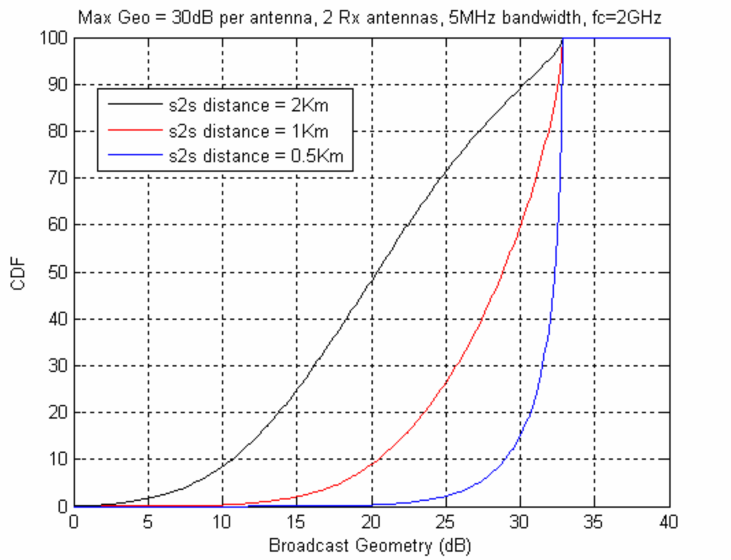

Figure 1 Broadcast geometry for various site-to-site (s2s) distances

Signal Decorrelations in a MIMO Broadcast System

In this section, we discuss the performance of a MIMO broadcast system in correlated fading. It is well known that spatial multiplexing may not be possible in a unicast system when the fading is perfectly correlated. However, we will show that in a broadcast channel, the fact that the same information is transmitted from multiple correlated antennas has the effect of de-correlating the channel, thus making spatial multiplexing possible. We consider the system shown in **Figure 2**.

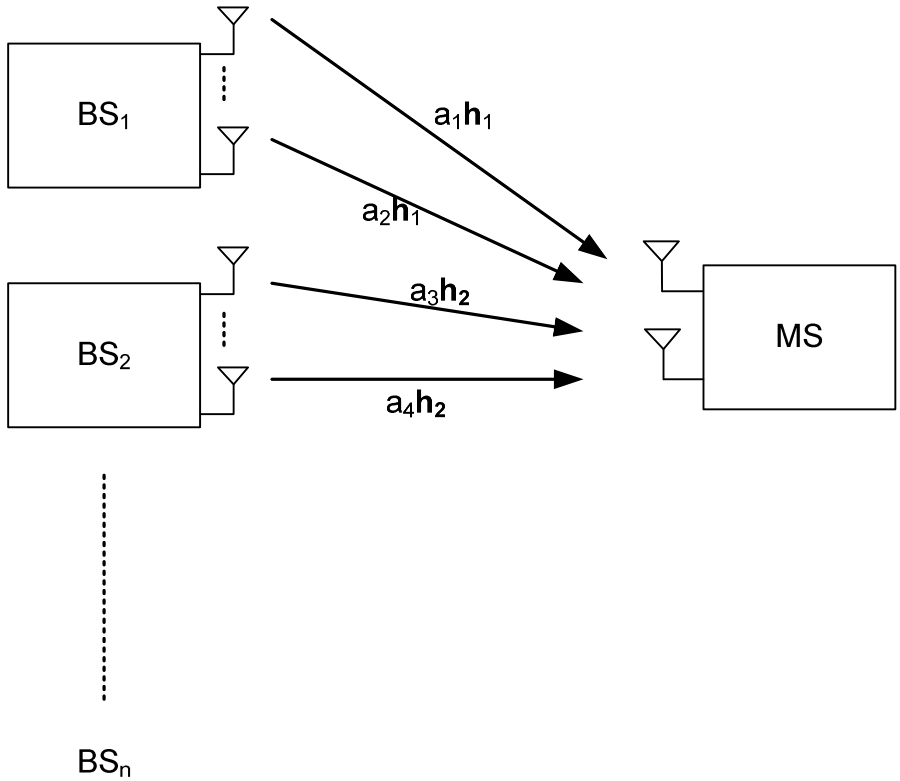

Figure 2 A Broadcast MIMO System

In this case, the 2 transmit antennas from a given BS is perfectly correlated. The BS is transmitting 2 streams, s_1 and s_2, and the MS receives on 2 uncorrelated receive antennas (as is typical in the SCM). Then $\mathbf{r} = \mathbf{h}_{1t}s_1+\mathbf{h}_{2t}s_2$. In this case $\mathbf{h}_{1t}= a_1\mathbf{h}_1 + a_3\mathbf{h}_2$, and $\mathbf{h}_{2t}= a_2\mathbf{h}_1 + a_4\mathbf{h}_2$, where $a_i \sim N_c(0,1)$ has a complex Normal distribution which represents the arbitrary complex scaling among the transmit antennas. These scalings exist because the transmit amplifiers among different BS's cannot be synchronized. Normally, in beamforming systems it is possible to use expensive antenna calibration systems to synchronize amplifiers from the same BS, however, we rely on the fact that no such systems are in place. Without loss of generality, we will assume that $\| \mathbf{h}_i\|=1$. In general when a mobile receives the same signals s_1 and s_2 from multiple correlated base stations, such that $\mathbf{h}_{1t} = \sum_i a_i\mathbf{h}_i$ and

$\mathbf{h}_{2t} = \sum_i b_i\mathbf{h}_i$

where $b_i \sim a_i \sim N_c(0,1)$, i.i.d. Clearly, when $\mathbf{h}_{2t} = \mathbf{0}$, (the unicast case) here the effective correlation between the stream antennas is $|\rho| = \frac{|\mathbf{h}_{1t}^H\mathbf{h}_{2t}|}{\sqrt{\mathbf{h}_{1t}^H\mathbf{h}_{1t}\mathbf{h}_{2t}^H\mathbf{h}_{2t}}} = \left|\frac{a_1a_2}{|a_1\|a_2|}\right| = 1$. Note that the correlation is only a function of the arbitrary complex scaling a_i. These complex scales are responsible for the decorrelation of the broadcast channel from multiple BS's. For 2 or more BS's, the correlation is a sum of multiple cross terms in both the numerator and the denominator. Unfortunately, the correlation does not simplify in a useful way for the case of multiple BS's, so a numerical simulation will be presented. We evaluated the effective correlation between 2 streams for the cases of between 1 and 10 BS's. For simplicity we consider a MS with equal geometry to all the BS's. The results are shown in **Figure 3**. In **Figure 4** we present a slightly different calculation which demonstrates the same effect. For simplicity we assumed that the MS has to implement a zero forcing (ZF) receiver to null the interfering stream in each case. We then plot the resulting SINR for the best stream in **Figure 4** as the number of BS's are increased. The -40dB for the single BS case should be –infinity, we just limited the graphical display range. From these results, we can conclude that under the worst possible conditions to do spatial multiplexing (perfectly correlated transmit antennas such as in line of sight conditions) for unicast traffic, it becomes possible to do spatially division multiplexing (SDM) with as few as 2 to 3 base stations in a broadcast SFN environment.

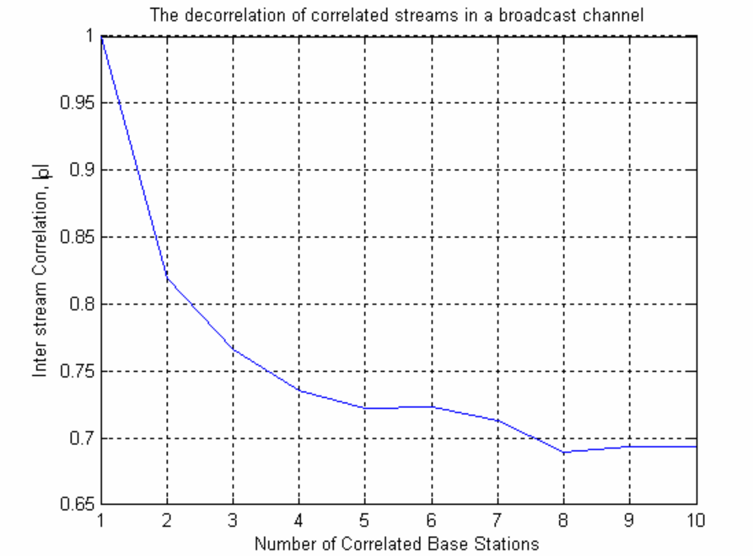

Figure 3 A Broadcast MIMO System

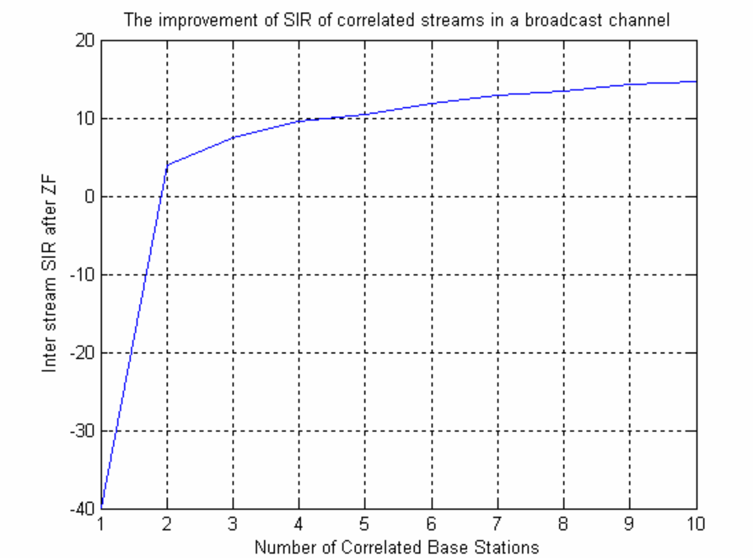

Figure 4 A Broadcast MIMO System

The previous results could be considered as overly pessimistic (and would thus overly emphasized the gains), so we looked at typical antenna correlation results based on calculations using the SCM channel model. In the SCM macro Urban Model, the 2 transmit antennas spaced 10λ apart could be correlated as mush as 80%-90%. In this case we show the decorrelation effect of multiple BS's in **Figure 5** and **Figure 6**. These results also indicate the same trend as the perfect antenna correlation case that the SFN broadcast environment is better suited for spatial multiplexing compared to the unicast case. In general, the spatial-multiplexed streams are less correlated as the mobile station moves away from the base station. This is due to the fact that potentially more base stations are received when a mobile station moves towards the cell edge. However, SINR probably may go down as the mobile station moves away towards the cell edge. The loss in SINR as the user moves away from the base station can potentially be compensated by increased de-correlations of the streams.

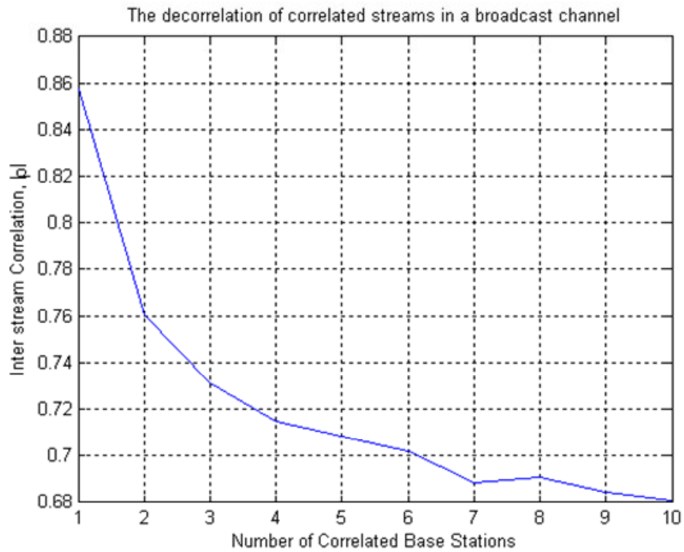

Figure 5 A Broadcast MIMO System

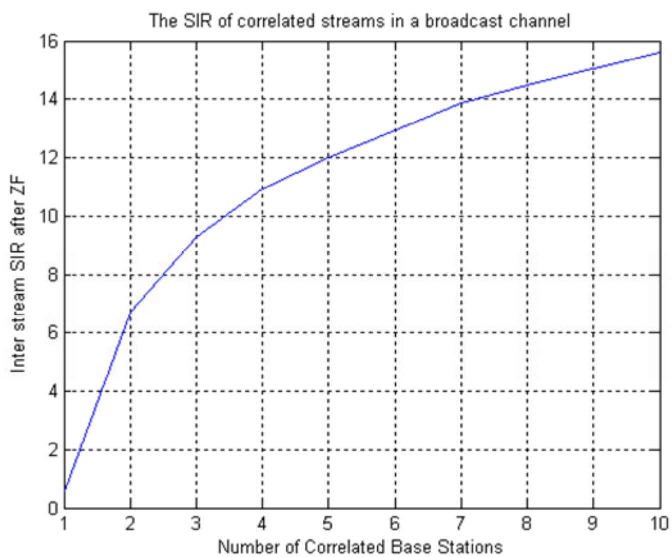

Figure 6 A Broadcast MIMO System

Summary

In the absence of any feedback from the mobile stations in MBSFN for E-MBS, the potential candidates for MIMO are either an open-loop transmit diversity scheme or an open-loop spatial multiplexing approach. Any form of additional transmit diversity is not expected to bring any significant benefit because MBSFN already enjoys from frequency-diversity due to delayed signals received from multiple cells. However, E-MBS service becomes bandwidth limited in an MBSFN operation and therefore spatial-multiplexing techniques become attractive. Moreover, the received signal from multiple cells sees increasing decorrelation in an MBSFN environment which also favors spatial multiplexing.

Both single codeword and multi-codeword spatial multiplexing schemes can be considered for E-MBS. In case of multi- codeword spatial multiplexing, dynamic adaptation of modulation and coding for each codeword is not possible due to absence of channel quality feedback. However, different codewords can potentially use different modulation and coding and/or power offsets etc. in a static fashion in order to enable efficient interference cancellation at the mobile station. Moreover, it is possible to transmit a base codeword and an enhanced codeword in case of multi-codeword transmission. This would allow base stations not supporting multiple transmit antenna to just transmit the base codeword. This would also enable users with disadvantaged channel conditions to only receive the base codeword and hence the E-MBMS service at a reduced QoS.

Therefore we propose to consider a spatial-multiplexing approach for MIMO evaluation in E-MBS.

Proposed Text for 16m SDD (802.16m-08/003r1)

Incorporate the following text in Chapter 15: Support for Enhanced Multicast Broadcast Service of the SDD:

To provide enhanced multicast and broadcast spectral efficiency in 16m, spatial multiplexing should be a transmission mode for E-MBS.

References

[1] Mark Cudak, IEEE 802.16m-07/002r4, "IEEE 802.16m system requirements"