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Re:	Response to the Call for Contributions IEEE 802.16m-08/016 — Hybrid ARQ
Abstract	This contribution proposes a HARQ protocol for MBS service for 802.16m system description document (SDD).
Purpose	To adopt the MBS HARQ protocol proposed herein into IEEE 802.16m system description document (SDD).
Notice	
Release	
Patent Policy	

HARQ for MBS

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1 Overview

Multicast Broadcast Service (MBS) is an important application for WiMAX services. It is useful both in the consumer space, and for applications like emergency communications and push-to-talk radio. In either case, it is desirable to make sure that all users (or a defined subset of users) get the multicast/broadcast message. The current provisions for MBS in the WiMAX standard are insufficient for providing reliability and/or energy and spectral efficiency. This contribution outlines possible improvements that could alleviate these problems in the next generation IEEE 802.16m system.

To start with an overview, the three key modifications that improve the situation are:

1) Use of mobile stations as relay stations to leverage the better transmission conditions that can occur between peer stations.

2) Use of beamforming to support broadcasting

3) Use of feedback to enable HARQ operation with incremental redundancy for multicast and broadcasting operation.

2 MBS Support in Current IEEE 802.16 System

In the current 802.16e standard, MBS is done without any feedback from the MSs at either layer 1 or layer 2. Therefore, *neither* ARQ *nor* HARQ is applicable to multicast connections. However MBS can be used with time-diversity allowing a HARQ-like behavior without ACK in 802.16e. The BS sends out “incremental redundancy” subpackets at different times; the MSs can then “piece together” the original information from those subpackets, which arrive with different quality (due to the time diversity). Note that this approach does not foresee any feedback, and there is thus no guarantee that each MS has received the broadcast packet (however, by using the channel state information, the BS can choose modulation and coding schemes that have high probability of supplying even the weakest desired user).

It must be noted that the amount of resources consumed by this approach is essentially determined by the weakest link between BS and all the available MSs, which can lead to low spectral efficiency of the MBS.

3 Proposed HARQ for MBS Protocol

The fundamental idea of this contribution is to transmit the multicast/broadcast message in the following stages:

1) The BS estimates all channels to the MSs. This estimation can be done by using the current 802.16 standard in the usual manner.

2) The BS selects an MCS that can be decoded by all MSs whose CQI is above a certain threshold, and can therefore be covered with good spectral efficiency. This transmission step is identical to the 16e HARQ MBS protocol.

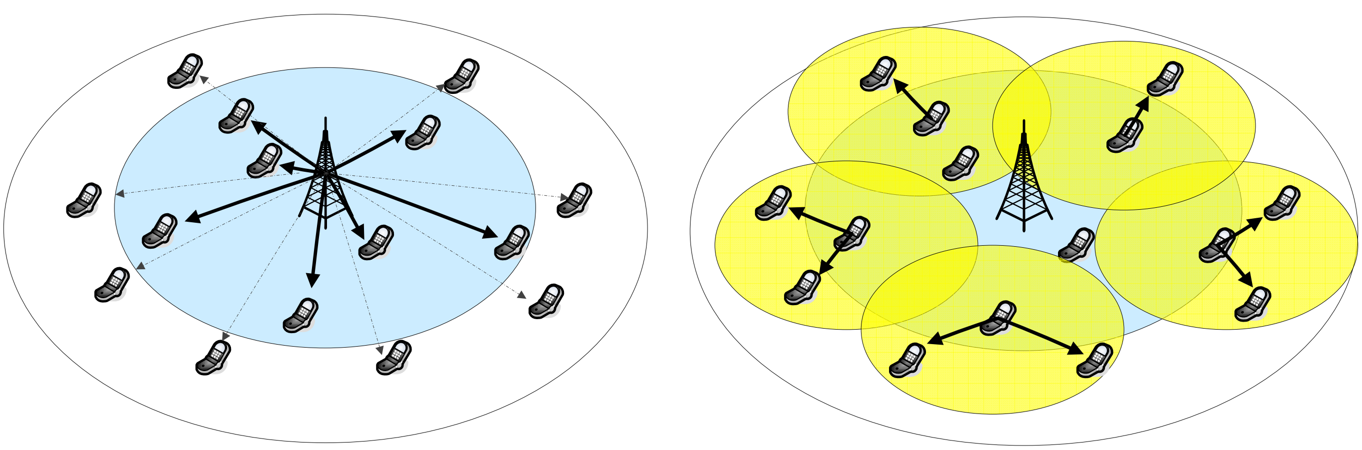
3) The MSs that properly received the message feed back an acknowledgement (ACK), and they (or a subset thereof) can henceforth act as "helper" MSs. The MSs that did not get the message (henceforth called "incomplete MSs") send a NACK, including how much additional information (incremental redundancy) they need for decoding. Furthermore, they will tell the BS about CSI of the channel between them and their potential candidates for helper MS.

4) The BS now decides which incomplete MSs should be completed by retransmission from the BS, and which should be supplied by other MSs. This decision can be influenced by interference considerations, concerns about battery lifetime for particular users, etc. It might also be useful if an MS can exchange information with the BS about how much information it is willing to forward (it could gain some "goodwill" or "tokens" for getting better service later on, when it is in need of forwarding). Anyway, the actual decision about forwarding is made by the BS according to manufacturer decisions, and need not part of the standard.

5) The BS now transmits HARQ packets (possibly with beamforming) to the incomplete MSs that it wants to supply directly. At the same time, it tells (e.g., in the MAP) which helper MSs should start to supply incomplete MSs; this also notifies certain incomplete MSs that they need to listen to information from the helper MSs.

6) If necessary, requests for further retransmissions can be sent; i.e., steps 3-5 are repeated until all MSs are complete or some target transmission reliability is reached.

The process is further illustrated in the following figure.



(a) transmission of the 1st HARQ subpacket by BS **(b) forwarding of subsequent HARQ subpackets by "helper" MSs.**

Figure 1: An illustration of HARQ MBS

Appendix: A Review of the Open Literature

Due to the low spectral efficiency of existing MBS schemes, there are a number of papers in the open scientific literature, treating the problem of efficient broadcasting with incremental redundancy codes. Those papers exploit the fact that some MSs (the ones with good channels to the BS) obtain the information very quickly if the BS uses a high-order AMC; those MSs then can relay the information to the other MSs. If bit-wise fountain codes are used, then the question of which AMC to use becomes moot, since each MS can collect as much mutual information as its channel state allows. MSs with weak channels to the BS collect only little mutual information in the direct transmission from the BS, and get more information when the “good” MSs relay the information to the bad ones. [1] suggested a “flooding” approach that propagates the information throughout the network. [2] analyzed a unicast setting (which can be easily modified to broadcast) to minimize the overall transmission energy and delay in a multihop network. [3] developed a fractional transmission scheme where the different relay nodes agree on how large a fraction of the required mutual information they send to other nodes. In all of those schemes, the retransmission by the MSs can happen in various hops.

However, those publications usually made the following assumptions:

1) Either only the BS can initiate retransmissions, or all stations in the network (including the BS) are at the same “level”, i.e., transmissions from the stations put equal constraints on the available resources.

2) There is either no, or perfect, central planning of the transmission route and decoding order. Note: The protocol by [4] actually provides for some fairly flexible arrangements where different nodes can send their acknowledgements, and missing mutual information can come either from the BS or from other MSs.

3) The transmitters are assumed to have only single antennas.

The situation in a WiMAX network is different from the above-mentioned assumptions: typically, transmission from a BS is easier than from an MS – both because relaying via an MS is more energy-critical (battery lifetime), and because MSs transmitting close to the cell edge can be the source of larger interference than a BS transmission that just reaches the cell edge.

Furthermore, the channel from the BS to the MSs is usually well known due to channel estimation and channel prediction, while the channels between the MSs are not known a priori, and the current standard does not foresee any methods to learn them. Even if new training methods are introduced in 16m that allow training of MS-MS channels (which we believe should be), it is still unrealistic to assume that all MS-MS channels are known – the training overhead would be too large. We thus need to find a protocol that can work with reduced training overhead.

Reference:

[1] A. F. Molisch, N. B. Mehta, J. Yedidia, and J. Zhang, “Cooperative relay networks with mutual-information accumulation”, IEEE Trans. Wireless Comm., 6, 4108-4119 (2007)..

[2] S. C. Draper, L. Liu, A. F. Molisch, and J. Yedidia , “Iterative Linear-Programming-Based Route Optimization for Cooperative Networks”, International Zurich Seminar on Communications, 84-87, 2008.

[3] N. Rahnavard, B. Vellambi, and F. Fekri, “FTS: A Fractional Transmission Scheme for Efficient Broadcasting via Rateless Coding in Multihop Wireless Networks”, IEEE MILCOM 2007.

[4] M. Busse, T. Haenselmann, and W. Effelsberg, “Energy-Efficient Data Dissemination for Wireless Sensor Networks”, Fifth Annual IEEE International Conference on Pervasive Computing and Communications Workshops, p. 301-306, (2007).