Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Relay-assisted Scheduling for Exploiting Multi-user Diversity on Access Links**
Date Submitted	**2007-01-08**
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Re:	IEEE 802.16j-06/034: "Call for Technical Proposals regarding IEEE Project 802.16j"
Abstract	A RS assisted scheduling scheme for MMR-BS operating in centralized scheduling service is proposed for exploiting multi-user diversity on the access links.
Purpose	For discussion and approval for inclusion of the proposed text into P802.16j baseline document.
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Relay-Assisted Scheduling for Exploiting Multi-User Diversity on Access Links

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1. Introduction

Most of the application scenarios for 802.16J consist mainly of two–hop networks [1]. While the relay stations (RS) can be static or mobile (nomadic), the user terminals (MS) are always assumed to be mobile as represented in figure 1. We are concerned with the centralized scheduling service. This allows for multi-user diversity (MUD) on the access links, although it may not be possible on the relay links. However, to exploit this MUD gain, the BS would have to obtain CQI from all the MS, as is currently achieved in 3G cellular networks and exploited in the form of channel-dependent scheduling. These CQI from the MS will be relayed to the BS by the RS for 16J usage scenarios. The CQI reports from the RS alone will not help avail MUD gain since MUD is available on the access links and not on the relay links. Thus, CQI reports from all the MS will be required, which will require a lot of feedback overhead. Our contribution in this proposal is to help the BS leverage the MUD gain on the access links without incurring a large feedback overhead, by making the RS assist in the centralized scheduling service.

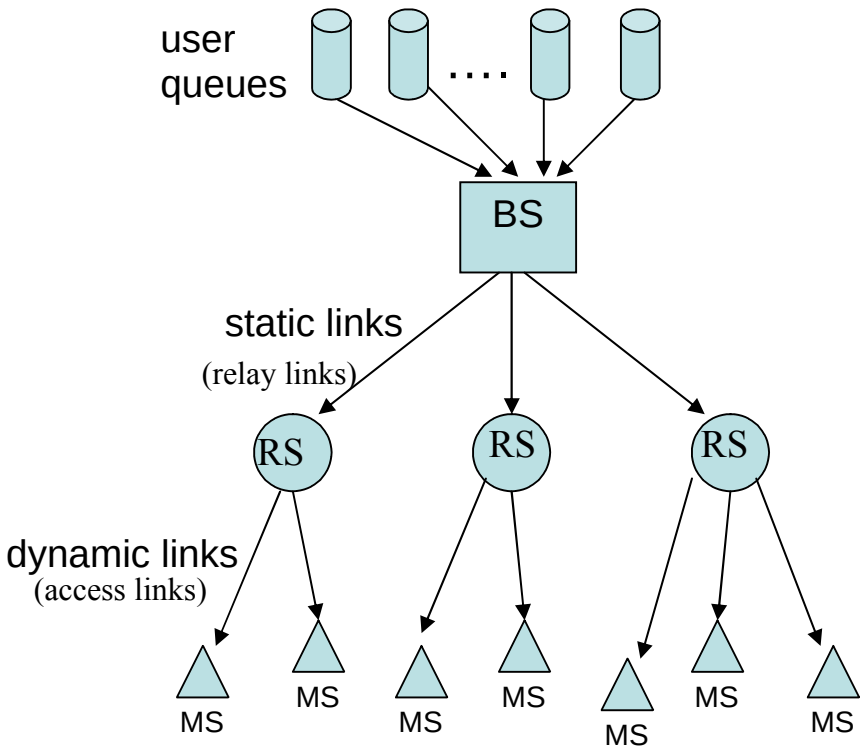

Figure 1. Topology Illustration

2. Centralized Scheduling Service

In centralized scheduling service, the RS are assumed to be simplified in terms of their functionality and all scheduling decisions are made at the BS. The RS will simply forward the scheduling requests and grants, report requests and grants, UL and DL maps, etc. between the BS and MS. It is the BS that has user queues (buffers) for each of the MS in its cell. The RS, being simplified, may not have per-user queues and consequently will not be able to directly leverage MUD gains on the access links even if allowed to perform scheduling on its own. Further, while exploiting MUD gains on the access links that are several hops away from the BS may not be feasible in centralized scheduling service due to latency constraints, it is very much feasible in two-hop cellular networks, which are the main focus and in fact mandatory for several important applications conceived for 802.16J [2]. In the case of access links being situated several hops away from the BS, MUD gains may be leveraged only through the distributed scheduling service, which is not the focus in this proposal.

3. Proposed Relay-Assisted Scheduling Service

Currently, whenever the BS requires CQI information from a MS, it transmits a REP-REQ towards the MS. The intermediate RS forwards the REP-REQ. Similarly, when the MS sends back the REP-RSP, it is once again forwarded by the intermediate RS to the BS. In TDD systems, it is possible for the RS to estimate the CQI for each of the MS served by it. However, it would still need to send back the REP-RSP for each of the MS when requested by the BS. This incurs a significant feedback overhead. We propose a relay-assisted scheduling service, whereby the RS assists the BS in its scheduling decision, thereby making it possible for the BS to exploit MUD on the access links without have to obtain the information from all the MS and hence avoid the large feedback overhead.

3.1. Proposed Mechanism

The BS may choose to exploit MUD by requesting CQI from all MS. This is unchanged to allow for backward compatibility. However, if the BS would prefer to exploit MUD without incurring the large feedback overhead and the resulting wastage of bandwidth resources, it allows the RS to assist it in its scheduling decision through notification in the REP-REQ message. The RS will then run the scheduling algorithm that is used by the BS. Note that the scheduling algorithm itself is outside the scope of this proposal. The RS will run the scheduling algorithm for the stations that are served by it. It does not however, schedule the user(s) once the outcome is obtained from the algorithm. Instead, it uses the outcome to generate a consolidated REP-RSP that provides the consolidated CQI of the user(s) that the RS has identified to be candidates for being scheduled in the particular frame. The BS collects this consolidated CQI information along with the set of users determined by its relay stations as potential candidates for the schedule. It then runs its own scheduling algorithm with the candidate set of users to determine the final set of user(s) who will transmit in the frame. This information is passed on to the RS as in the normal centralized scheduling process. Thus, the RS performs assisted scheduling in determining the candidate set of MS to exploit MUD, and providing consolidated CQI information to the BS to leverage these MUD gains without

increasing the overhead. The specific metric for obtaining the consolidated CQI is again outside the scope of this document.

4. Advantages

- The fact that RS have more important information on the channel state of access links is exploited at the BS through relay-assisted scheduling to leverage MUD gains. If 'M' is the number of mobile stations per relay and if 'R' is the number of relays, the total diversity order that can be obtained is 'MR'.
- Feedback overhead does not increase with number of users unlike in the conventional centralized scheduling service, where it is order of 'MR'. However, in relay-assisted scheduling, every relay sends back only a consolidated CQI, reducing the feedback overhead to order of 'R', which is an order of 'M' reduction.
- Complete backward compatibility with existing 802.16e is maintained. Relay-assisted scheduling is leveraged only if BS requests for the functionality from RS.
- Additional MUD gain is possible with multiple paths to MS, which in turn are required for fault tolerance and load balancing. If 'k' is the number of multiple paths to every MS, the potential MUD order now increases to 'kMR'. In this case, the corresponding overhead of the conventional scheduling scheme will also increase to order of 'kMR'. However, the overhead for the relay-assisted scheme will continue to remain the same, order of 'R', thereby proving to be highly scalable when compared to conventional scheme with an overhead reduction order of 'kM'.
- The reduction in overhead also applies to the case of multi sub-channels in OFDMA.

A schematic representation of the potential gains is presented in Figure 2.

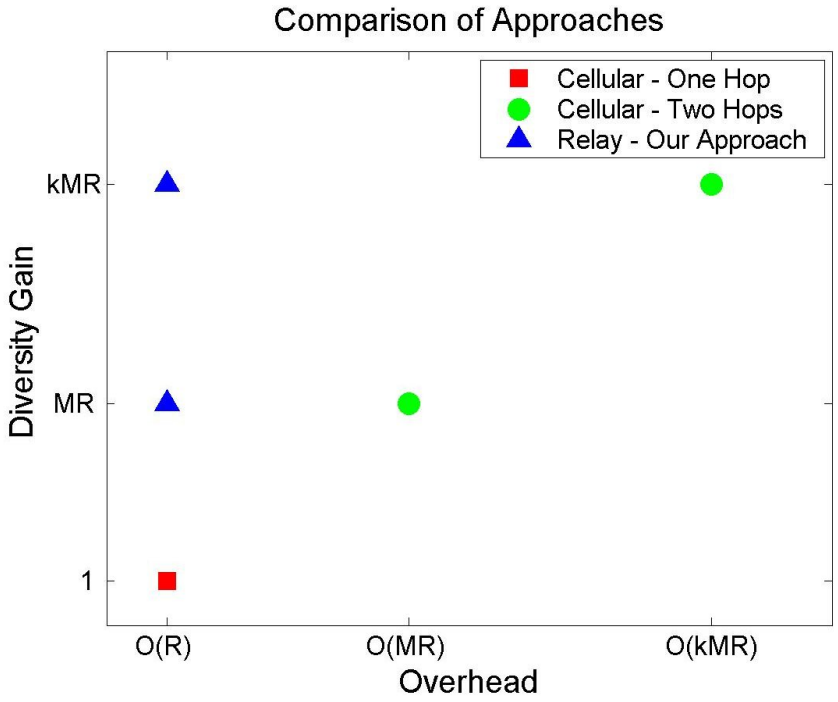

Figure 2. Potential Gain Illustration

"Cellular – One Hop" represents the conventional centralized scheduling service, where the MMR-BS exploits only the CQI on the relay links in its scheduling algorithm for scheduling the relay links in its cell. "Cellular – Two Hops" represents the conventional centralized scheduling service but with the MMR-BS obtaining information from all the MS on the access links through the RS; and exploiting this information in the schedule of the relay links in order to exploit MUD on the access links. "Relay – Our Approach" represents the relay-assisted centralized scheduling service at the MMR-BS, where relay-consolidated CQI is used in the scheduling of the relay links in order to exploit MUD on the access links.

5. Changes to Specification

Note that all the existing mechanisms for scheduling services such as scheduling requests/grants, bandwidth requests/grants, etc. remain the same. In order for the BS to have the option of exploiting MUD gain on the access links through reduced control message overhead, we propose the following text proposal changes. Essentially, the BS in its centralized scheduling service, is provided the functionality of requesting for consolidated channel measurement reports from its relay stations, which send back the consolidated reports along with the candidate set of user(s) in their response. This is accomplished with the following changes to the MAC Management Messages, namely the channel measurements request and response reports: REP-REQ and REP-RSP.

Use the reserved field in the REP-REQ management message encoding to ask for consolidated report.

Change the reserved entry in the Channel Type request field of the REP-REQ table in 11.11 from "reserved" to "Consolidated subchannel".

Name	Type	Length	Value
Report type	1.1	1	Bit #0 = 1 Include DFS Basic report Bit #1 = 1 Include CINR report Bit #2 = 1 Include RSSI report Bit #3-6 α_{avg} \ in multiples of 1/32 (range [1/32, 16/32]) Bit #7 = 1 Include current transmit power report
Channel number	1.2	1	Physical channel number (see 8.5.1) to be reported on (license-exempt bands only)
Channel Type request	1.3	1	00 = Normal sub-channel, 01 = Band AMC channel, 10 = Safety channel, 11 = ~~Reserve~~d Consolidated subchannel

Since the existing fields should not be changed for backward compatibility, the reserved field is used by the BS to request for consolidated report for a sub-channel.

The corresponding addition to the REP-RSP is as follows.

Insert the following final row entry into the Channel Type encoding table for REP-RSP in 11.12 for Channel type = 11.

REP-REQ Channel Type Request	Name	Type	Length	Value
Channel Type = 00	Normal sub-channel report	2.1	1	First 5 bits for the CINR measurement report and the rest for don't care
Channel Type = 01	Band AMC report	2.2	4	First 12 bits for the band indicating bitmap and the next 20 bits for CINR reports (5 bits per each band)
Channel Type = 10	Safety Channel report	2.3	5	First 20 bits for the reported bin indices and the next 20 bits for CINR reports (5 bits for each bin)
Channel Type = 11	Consolidated Sub-Channel report	2.4	1	First 5 bits for the CINR measurement report and the next 3 bits for indicating the candidate MS id in the relay's cell

6. References

[1] Usage Models (IEEE 802.16j-06/015)
< http://ieee802.org/16/relay/contrib/802.16j-06_015.pdf>

[2] Technical requirement (IEEE 802.16j-06/016r1)
< http://ieee802.org/16/relay/contrib/80216j-06_016r1.pdf>,