Project	**IEEE 802.16 Multihop Relay Project < http://ieee802.org/16/relay/index.html >**
Title	**Directional Distributed Relay with Interference Control and Management**
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Re:	This is a response to a Call for Technical Proposal regarding IEEE Project P802.16j issued on 24th October 2006 http://ieee802.org/16/relay/docs/80216j-06_027.pdf
Abstract	This document proposes a directional distributed relay with interference control and management for 802.16j relay mode.
Purpose	A partial technical proposal submitted IEEE 802.16j TG for considerations and further discussions.
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Directional Distributed Relay with Interference Control and Management

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Introduction

This document proposes a directional distributed relay with interference control and management. This contribution is a response to Call for Technical Proposal of IEEE802.16j which was issued on 24th October 2006. WiMAX is well-known for long distance transmissions and high data capacities. However, power and spectral efficiency is key to successful deployment. Radio relay deployment achieves both coverage enhancement and capacity improvement. However, radio resource efficiency becomes a major challenge for relay systems. Effective system spectral efficiency is one of the major performance metrics been defined [1]. Radio resource sharing (taking interference issues into account) is a requirement of 16j [2]. This contribution is to meet the resource sharing requirement in order to achieve high spectral efficiency for 802.16j relaying mode.

Effective system spectral efficiency of multi-hop relay

Based on the definition of the effective system spectral efficiency [1], there are two approaches to ensure the effective efficiency. One is to increase the system data throughput, such as employing high level AMC (e.g., 3/4-rate 64QAM). Another is to reduce the radio resource applied to the system. With a limitation of employing higher level AMC schemes (3/4-64QAM is the highest mode as defined in 802.16e [3]), radio resource efficiency becomes a key challenge and radio resource sharing has to be considered for a relay deployment.

With the effective system spectral efficiency, we also introduce an effective relay efficiency as

$$\xi_c = \frac{\sum_{i=1}^{s-p} C_i^{BS} + \left(\sum_{j=1}^{p} C_j^{RS} \right) \Big/ N_{rc}}{\sum_{k=1}^{s} C_k^{BS}},$$

where s presents the number of total users within the cell coverage (including all coverage holes) and p presents the number of users connected through relay station(s) (RS(s)). N_{rc}, C^{BS} and C^{RS} denotes number of radio resource employed by relaying, the capacity without relaying (access link capacity), and the capacity with relaying (relay link capacity) respectively.

Without radio resource sharing, the system deployment is applying each radio resource on each link, including BS-RS, BS-MS, RS-RS and RS-MS. For clearer demonstration, we demonstrate a simple relay deployment for a Single-Input-Single-Output (SISO) system and with a single user. We define a relay SNR-gain as $G_{SNR} = SNR_{relay} - SNR_{access}$ (dB), where the SNR_{relay} and SNR_{access} is the signal to noise ratio of the relay link (RS-MS) and the access link (BS-MS) respectively. Figure 1 shows that, the relay efficiency is not linearly increased with the G_{SNR}. Also, for a certain required efficiency, the G_{SNR} is different according to different SNR_{access}.

It also indicates that the requirement of the relay SNR gain is much lower if the access SNR is low, e.g., while access SNR is -10 dB, the relay SNR-gain only needs about 3 dB for 100% of relay efficiency. But more than 10 dB relay SNR-gain is required for the access SNR of 10 dB in order to maintain reasonable relay efficiency.

Basically, it requires a higher relay throughput gain in order to leverage the single link throughput and the system throughput.

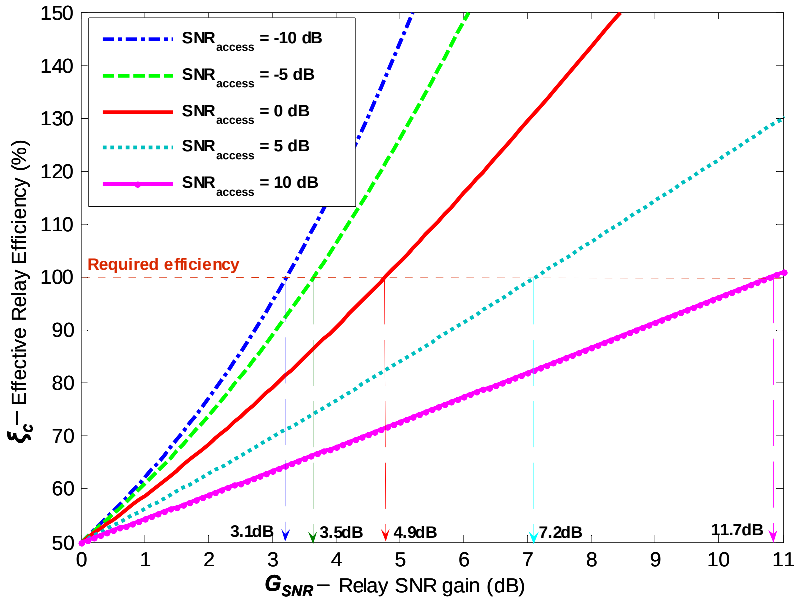


Figure 1: Figure 4. Analysis of relay SIR required for high efficiency (2-hop with fully shared radio resource)

With resource sharing, the critical issue is the interference introduced into the system. Figure 2 illustrates the impact of the interference on the relay efficiency, based on a SISO system with 2-hop, where SIR is much acceptable for access-SNR not greater than 10 dB (in order to achieve equivalent or higher relay efficiency). The interference impact is only on relay link if we assume that there is no interference to the access link.

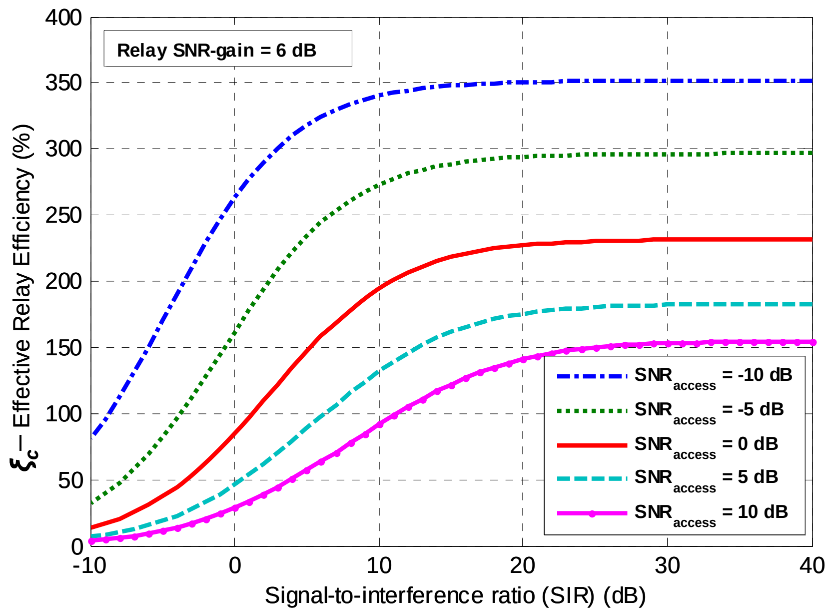


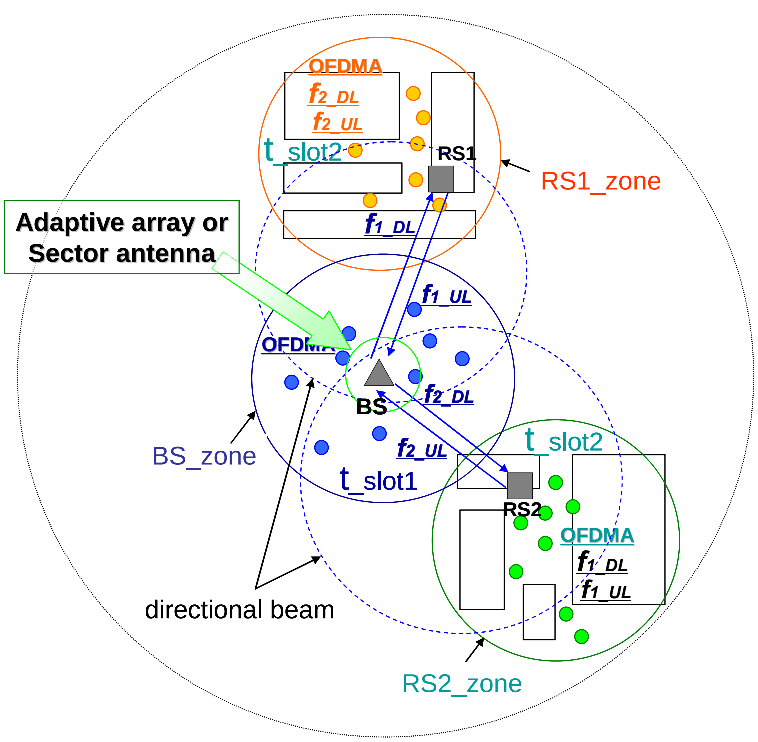
Figure 2: Analysis of relay SNR-gain required for high efficiency (2-hop with two radio resource, no resource sharing)

In fact, the interference strength is highly depend on the usage scenario, which is quite difficult to model. However, from our experience, SIR less than 10 dB can be easily achieved by spatial separation in the relaying system. For SIR between 10 dB to 20 dB, simple array processing (including sector antenna) might be required. Interference avoidance is a processing technique to achieve higher system performance. For higher SIR, such as SIR>25dB, there will be much less impact on transmission ($SNIR_{req}$ assumptions for 64-QAM is 23.0 dB, for uncoded signals at 10^{-3} BER).

Furthermore, with a fixed access SNR and a fixed relay SNR-gain (for a MS access at a transmission slot), the maximum throughput of the relay with resource sharing can be doubled compared to the relay without sharing.

Directional distributed relay

In order to support high efficient relay, the system should have a suitable topology to fully take advantage of spatial separation and effective resource assignment as defined in 802.16e [3]. For this purpose, a directional distributed relaying architecture with a paired radio-resource transmission scheme is proposed and depicted in Figure 3. The radio resource (*f*) can be either frequency, time slot or fractional frequency (e.g., sub-channel in OFDMA). The transmission in the BS_zone is the same as that of the 802.16e. For relaying transmission, a paired transmission is applied, where BS forms two directional beams or use two sector antennas to make transmission with RS1 and RS2 simultaneously. For the radio resource, we also use a paired resources: *f1_DL - f1_UL* and *f2_DL – f2_UL*. The first pair of *f1_DL - f1_UL* is applied to BS-RS1 and RS2_zone; the second pair of *f2_DL – f2_UL* is applied to BS-RS2 and RS1_zone.



f – radio resource; DL – down Link; UL – Up Link; zone – coverage area

Figure 3: Directional distributed relaying with paired radio-resource

Interference control and management

It is clear that the radio resources are shared between RSs and MSs, where each end-user employs only one radio resource in average. Also by this kind of sharing, the interference can be easily controlled by the BS and the RS. The interference of this configuration is illustrated in Figure 4. There are only two set of interference in this relay configuration. The interference between BS and MS-groups can be detected and controlled by the BS. Firstly the BS could employ adaptive array for spatial separations. Secondly, since the power from each MS of each MS-groups is know to the BS, interference avoidance can be applied between the two groups by the BS. Furthermore, this kind of interference should be small as that the BS allocates the MSs through relay, which means that the relay SNR-gain should be much higher than the access SNR level. Another set of interference between RSs can be canceled by adaptive array (AA) deployment at the RSs, which is also feasible.

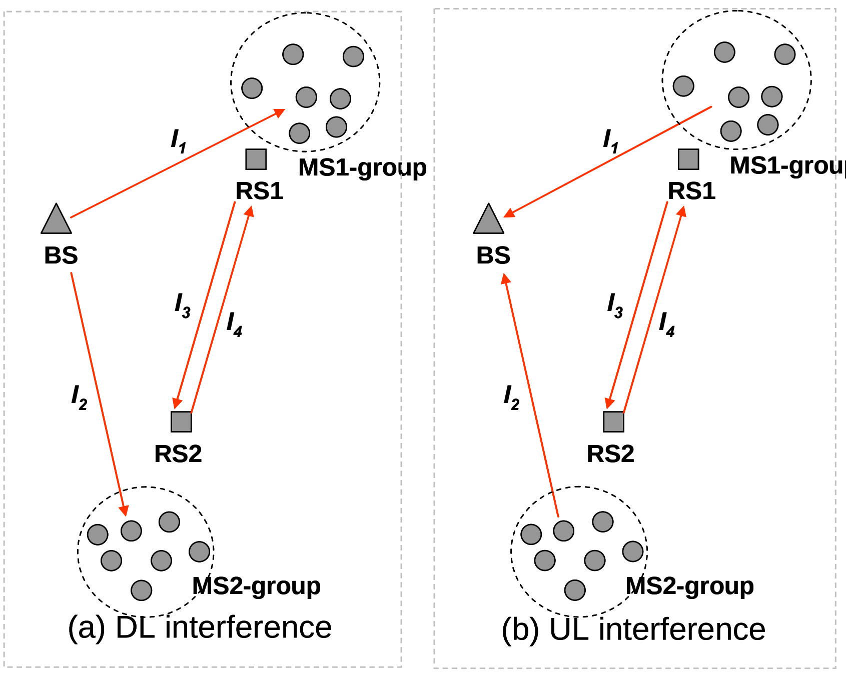


Figure 4: Interference illustration for the directional distributed relaying

The proposed topology is fully compatible with the existing 802.16e since there is no any modification required on MSs'. It is a 16e system without much difference (only the BS needs to aware of the existence of the RSs).

This deployment is suitable to any relaying mode (FRS, MRS and NRS). Also, it is suitable for any scenarios such as coverage hole, extension relaying, etc. Combine this with the fractional frequency re-use, edge interference can be further avoided. In addition, any varies of the deployment are allowed, such as more than the paired-resources, say three radio resources, sharing scheme can be applied between the three with more flexible interference control and management [5].

Requirements for the deployment

There are several requirements for the directional distributed relay deployment:

- The MR-BS and RSs have to have directional arrays, at least, sector antennas.
- The MR-BS has to have the knowledge of the MSs' behaviors of each relay zone, such as the received power to the MSs (DL) and/or received power at the MR-BS (UL).

- The RSs have to have message exchange to initiate the directional arrays to eliminate/avoid inference to each other.

References

[1] IEEE 802.16j-06/013r1, “Multi-hop Relay System Evaluation Methodology (Channel Model and Performance Metric)”, 2006-10-11.

[2] IEEE 802.16j-06/016r1, “Proposed Technical Requirement Guideline for IEEE 802.16 Relay TG”, 2006-10-11.

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[4] IEEE Std 802.16–2004, “Part 16: Air Interface for Fixed Broadband Wireless Access Systems”, IEEE, 2004-10-01.

[5] C80216j-06_223, “Fractional Frequency Reuse for IEEE802.16j Relaying Mode”, Technical proposal submitted to IEEE 802.16j TG, 2006-11-07.