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Re:	IEEE 802.16j-06/027: "Call for Technical Proposals regarding IEEE Project P802.16j"
Abstract	Resource reuse is an essential feature in multihop relay networks to enhance the system throughput. More aggressive resource reuse could lead to performance improvement. Nevertheless, interference between radios sharing the same resource needs to be well regulated and controlled to avoid system performance degradation. In this contribution we propose a framework and define messages to support adaptive interfere management scheme.
Purpose	For discussion and approval of inclusion of the proposed text into the P802.16j baseline document.
Notice	
Release	
Patent Policy and Procedures	

Resource reuse and interference management mechanism

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1. Introduction

In an MR-enabled network, an MR-BS may communicate with an SS directly or via an RS. When an RS relays traffic toward an SS on behalf of an MR-BS, it enhances the signal quality and the coverage because of its proximity to the SS. Similarly signal quality is also enhanced when an RS forwards traffic from an SS to an MR-BS.

Resource reuse could be achieved, where communications between different pairs of MR-BS, RS and SS are carried out simultaneously. Figure 1 illustrates three scenarios of resource reuse including (1) RS⇔SS and RS⇔SS, (2) MR-BS⇔SS and RS⇔SS, and (3) MR-BS⇔RS and RS⇔SS. For example, in the left most scenario, two pairs of RS and SS use the same frequency (or subchannel) and symbol to communicate.

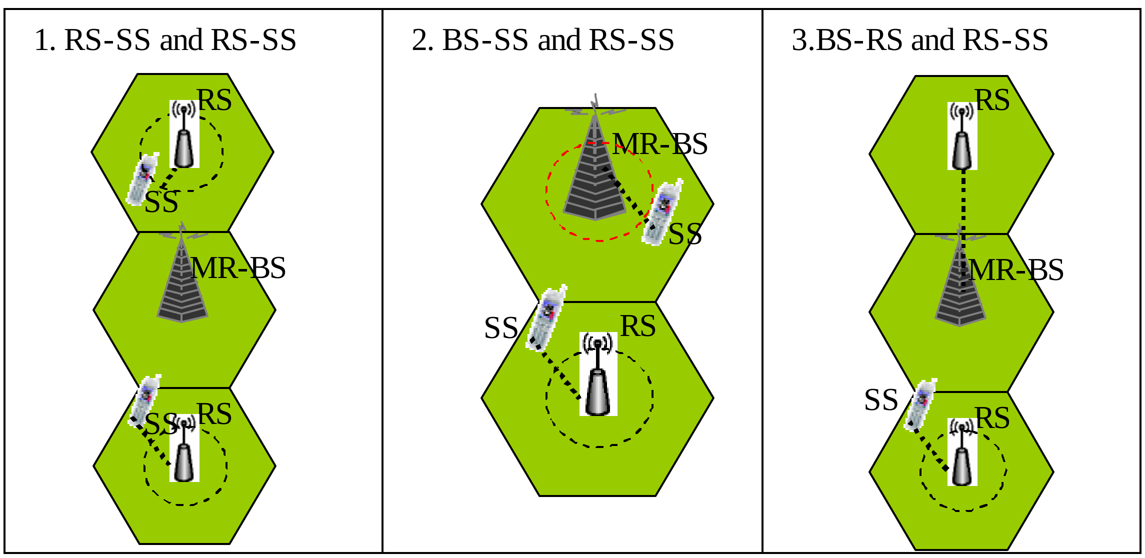

Figure 1 Three scenarios of resource reuse in MR networks

Each of the 2-dimensional area defined in MR-BS's frame structure and in RS's frame structure denotes a data transmission. If two data transmissions are happening far apart, and there is no possibility of signal interference, their corresponding 2-d areas could overlap with in *both* time and frequency domain. In other words, resource reuse is possible.

In this contribution and [1], we propose a resource reuse and interference management framework to improve overall system capacity of MR networks. The proposed solution includes a workflow to mitigate the interference issues while enabling the resource reuse as much as possible. In [1], MR-BS estimates an initial interference matrix to determine whether two RSs within the same MR-cell would interfere with each other based on the collected measurements from all RSs. Then in this contribution, a calibration procedure based on the measurements and feedbacks from MSs is proposed to adjust the resource reuse usage and reduce the interference level.

2. Resource reuse and interference management for multihop relay networks

Resource reuse is an essential feature in MR networks to enhance the system throughput. More aggressive resource reuse could lead to performance improvement. Nevertheless, interference between radios sharing the same resource needs to be well regulated and controlled to avoid system performance degradation. In this contribution a workflow of interference management and resource reuse is described to support adaptive interfere management scheme in MR networks. The procedures consist of five steps:

1. Interference measurement in MR-cell
2. Resource allocation by MR-BS
3. DL/UL Map determination in RS cell
4. Interference indication from SS
5. Adjustment of resource allocation across MR-BS cell

The first step of interference measurement is described in [1] while the other four steps are presented in this contribution.

2.1 Resource allocation by MR-BS

Each composition of time slot and subchannel denotes a resource, and the resource may be shared (or reused) among pairs of MR-BS, RS, and SS connections. Based on the initial interference matrix and the traffic demand in MR-BS and RS cells, MR-BS decides the DL/UL map of its MR-BS cell frame structure.

Each RS is instructed by MR-BS about the resource available for RS cell communication. The resource for each RS cell may differ to avoid interference, but may also overlap to allow resource reuse. In Figure 2, an example of resource allocation for RS is shown. For ease of illustration, these resources are assumed to cover the same set of sub-carriers, so the frequency dimension is not depicted. For each piece of resource (which is 1-dimensional time slot in Figure 2), each RS is designated as a primary user or secondary user. The information of indicating the primary user or secondary user is defined in MR_DL_Allocation_IE and MR_UL_Allocation_IE [2]. When the bit “Secondary usage indication” is enabled, the receiver of MR_DL_Allocation_IE or MR_UL_Allocation_IE would know it is the secondary user. The secondary user shall give the priority of transmission to the primary user if interference is detected. For example, RS1 is a secondary user of the spectrum in time [t2, t3], and a primary user in time [t3, t4]. As a primary user, RS cell communication could proceed without concerns of interference. For example, RS4 cell of Figure 2, is assumed to be far away from other RS cells, thus it is a primary user over time [t1, t4]. This could be determined by the initial interference matrix, if $I_{1,4}$, $I_{2,4}$, $I_{3,4}$ are all zeros.

By contrast, there are potential interfere among RS1, RS2, RS3 cells, which is also determined by the initial interference matrix. Over time [t2, t3], RS3 cell is the primary user, while RS1 and RS2 cells are denoted as the secondary (depicted by shaded area in Figure 2)

It shows that RS1 and RS 2 cell communication reuse the resource that has been primarily used by RS3 cell over time [t2, t3]. Depending on the location and power level of the associated SS, the interference may or may not actually occur. Suppose interference does occur, the RS1 or/and RS2 may need to back away and adjust the UL/DL map, such that their intra cell communication does not interfere with that of primary user, RS3 cell.

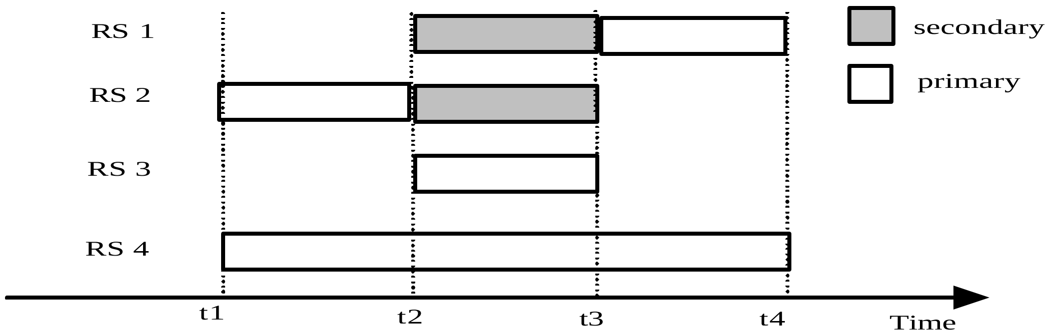

Figure 2 An example of resource allocation for RS cell.

2.2 DL/UL Map determination in RS cell

Given resource allocation in Figure 2, each RS further divides the resource for communication to and from its associated SS, by setting proper DL/UL map in intra RS cell frame structure. First the RS will try to use the resource for which it has been designated as secondary users in order to take advantage of resource reuse. If the interference occurs at particular SS *i*, then the communication between RS and SS *i* may be moved to the resource for which the RS is a primary user. Different policies can be used to determine which SS' data transmission may be allocated on the secondary resource. The algorithm of determining SS's data transmission at RS is outside the scope of this standard.

2.3 Interference indication from SS

When an RS allocates its secondary resource for communication with an SS, there is a possibility of interference. If the interference occurs at the RS reception, RS could easily detect it. Suppose the interference occurs at SS reception, the feedback from SS is needed for RS to respond to the interference.

There are many ways for RS to receive the interference indication. Two examples are introduced below.
1. ARQ fast feedback:
Using the acknowledgement of ARQ, RS can infer the interference at SS. If many re-retransmissions occur, then interference is assumed to happen at SS.
2. Explicit measurement:
RS could request SS to report signal quality (RSSI or CINR) measurement results through REP-RSP.

Once interfere is determined, RS may re-allocate its primary resource for the interfered SS communication. However, RS doe not have to avoid the secondary resource completely. The secondary resource may still be used for communications with remaining SS. Note that interfere depends on the SS location, so it shall be evaluated on a per-SS basis.

2.4 Adjustment of resource allocation across MR-BS cell

In addition to the adjustment of resource allocation at level of RS cell, the resource allocation may also be adjusted with a larger scope at level of MR-BS cell. The adjustment is needed for many reasons including the followings:

1. Change of traffic demand:
The resource MR-BS allocates to each RS cell may correspond to the traffic demand with the associated SS. When traffic demand changes, the adjustment is needed.

2. Insufficient primary resource at RS cell:
MR-BS allocates primary resource and secondary resource to RS cell. In each RS cell, the secondary resource is allocated first to take advantage of resource reuse, and primary resource allocated to avoid interference. If primary resource is insufficient to support required interference-free communication, then MR-BS may adjust the allocation.

3. Interfered communication on primary resource:
If intra RS cell communication is interfered on secondary resource, then this communication may be reallocated to a primary resource as previously discussed. However, a communication in RS cell *i* on secondary resource may not detect being *interfered*, but actually cause interference on communication of RS cell *j* which is on primary resource. In such a case, RS cell *i* is not aware of the interference. RS cell *j* can not effectively mitigate the interference and needs to notify MR-BS to adjust resource allocation so the resource is not shared among RS cell *i* and *j*.

3. Specific text changes

Insert a new subclause 6.3.27:

6.3.27 Resource reuse and interference management for multihop relay networks

Resource reuse is an essential feature in MR networks to enhance the system throughput. More aggressive resource reuse could lead to performance improvement. Nevertheless, interference between radios sharing the same resource needs to be well regulated and controlled to avoid system performance degradation. In this subclause a workflow of interference management and resource reuse is described to support adaptive interfere management scheme in MR networks. The procedures can be categorized into two major steps: (1) Interference measurement in MR-cell and (2) Resource reuse allocation and calibration.

Insert a new subclause 6.3.27.2:

6.3.27.2 Resource reuse allocation and calibration for multihop relay networks

Each composition of time slot and subchannel denotes a resource, and the resource may be shared (or reused) among pairs of MR-BS, RS, and SS connections. Based on the initial interference matrix and the traffic demand in MR-BS and RS cells, MR-BS decides the DL/UL map of its MR-BS cell frame structure.

Each RS is instructed by MR-BS about the resource available for RS cell communication. The resource for each RS cell may differ to avoid interference, but may also overlap to allow resource reuse. An example of resource allocation for RS is shown in Figure 130j. For each piece of resource, each RS is designated as either a primary user or secondary user. The information of indicating the primary user or secondary user is defined in MR_DL_Allocation_IE (8.4.5.3.28) and MR_UL_Allocation_IE (8.4.5.3.29). When the bit "Secondary usage indication" is enabled, the receiver of MR_DL_Allocation_IE or MR_UL_Allocation_IE shall be the secondary user and shall give the priority of transmission to the primary user if interference is detected.

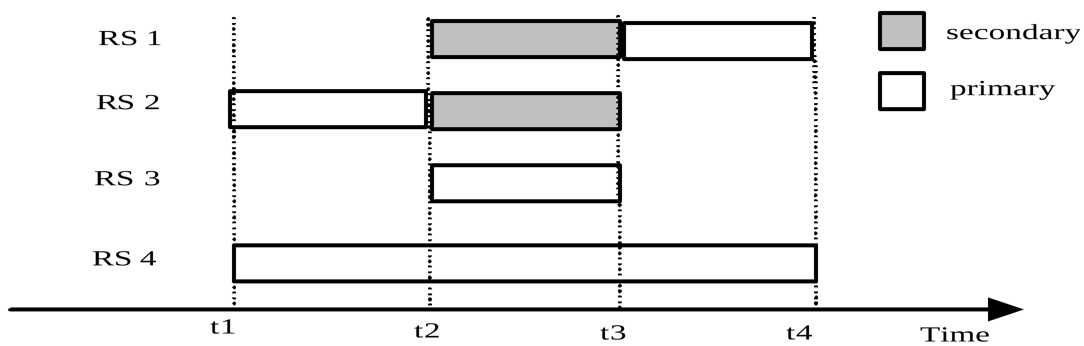

Figure 130j An example of resource allocation for RS cell.

RSs may make scheduling decision locally and allocate data transmission to an SS either on the primary or secondary resource. The algorithm of determining SS's data transmission at RS is outside the scope of this standard.

When a RS allocates one secondary resource to an SS, there is a possibility of interference. If the interference occurs at the RS reception, RS could easily detect it. Suppose the interference occurs at SS reception, the feedback from SS may be needed for RS to respond to the interference. Upon detecting interference for an SS, RS may re-allocate its primary resource for the interfered SS communication.

In addition to the adjustment of resource allocation at level of RS cell, the resource allocation may also be adjusted with a larger scope at level of MR-BS cell. The adjustment of resource reuse may be needed when the traffic demands of RS cells change or an RS encounters severe interference from other RSs. The algorithm of adjusting resource reuse is outside the scope of this standard.

Insert new subclause 8.4.5.3.28:

8.4.5.3.28 MR_DL_Allocation_IE

Insert the following table in 8.4.5.3.28:

Table 286aa – MR DL Allocation

Syntax	Size	Notes
MR_DL_Allocation_ IE(){		
Extended DIUC	4 bits	MR_DL_Allocation_IE = 0x09
Length	4 bits	
MR midamble present	1 bit	0b0 = No midamble 0b1 = Midamble is first symbol in the allocation.
R-DL duration present	1 bit	0b0 = No duration field present, R-DL extends to the end of the subframe 0b1 = Duration field is present, R-DL defined by this IE has a defined duration
FCH and MAP DIUC	4 bits	DIUC used to transmit the FCH and MAP messages on the R-Link.
R-DL OFDMA symbol offset	8 bits	Location of the R-DL interval relative to the frame start.
if (R-DL duration present = 1) {		
R-DL duration	8 bits	Duration of the R-DL interval in symbols.
}		
Secondary usage indication	1 bits	Indication of region where the burst locates at is shared with other stations and furthermore the receiver of this IE is the secondary user
}		

Insert new subclause 8.4.5.3.29:

8.4.5.3.29 MR_UL_Allocation_IE

Insert the following table in 8.4.5.3.29:

Table 286ab – MR UL Allocation

Syntax	Size	Notes
MR_UL _Allocation_IE(){		
Extended UIUC	4 bits	MR_UL_Allocation_IE = 0x0B
Length	4 bits	

R-UL duration present	1 bit	0b0 = No duration field present; R-UL extends to the end of the subframe. 0b1 = Duration field is present; R-UL defined by this IE has a defined duration.
OFDMA symbol offset	8 bits	-
if (R-UL duration present = 1) {		
R-UL duration	8 bits	Duration of the R-UL interval in symbols.
}		
Secondary usage indication	1 bits	Indication of region where the burst locates at is shared with other stations and furthermore the receiver of this IE is the secondary user
}		

4. References (if required)

[1] W-P Chen et al., "Estimation of the initial interference matrix," IEEE C802.16j-06/148, November 7, 2006.
[2] M. Hart et al., "Frame structure for multihop relaying support", IEEE C802.16j-06/138, November 7, 2006.