Project	IEEE 802.16 Broadband Wireless Access Working Group <**http://ieee802.org/16**>
Title	A Flexible Multi-hop Frame Structure for IEEE 802.16j
Date Submitted	2007-03-05
Source(s)	David Comstock, John Lee, Zheng Shang, Jingning Zhu Huawei Technologies No.98, Lane91, Eshan Road, Shanghai, P.R.C dcomstock@huawei.com Voice: +1 858 735 9382
Re:	IEEE 802.16j-07/007r2: " Call for Technical Comments and Contributions regarding IEEE Project 802.16j"
Abstract	This contribution describes the proposed frame structure for supporting both relay link and access link in a single TDD OFDMA frame.
Purpose	This contribution is submitted for discussion and adoption in 802.16j.
Notice	This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.
Release	The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.
Patent Policy and Procedures	The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures <http://ieee802.org/16/ipr/patents/policy.html>, including the statement "IEEE standards may include the known use of patent(s), including patent applications, provided the IEEE receives assurance from the patent holder or applicant with respect to patents essential for compliance with both mandatory and optional portions of the standard." Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <mailto:chair@wirelessman.org> as early as possible, in written or electronic form, if patented technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.16 Working Group. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>.

A Flexible Multi-hop Frame Structure for IEEE 802.16j

David Comstock, John Lee, Shang Zheng, Aimin Zhang

1 Introduction

In response to the IEEE 802.16j TG Call for Contributions, this document proposes a flexible and backward-compatible frame structure to support multi-hop relaying.

The IEEE 802.16j[1] PAR specifies that the scope of the project is:

"OFDMA physical layer and medium access control layer enhancements to IEEE Std 802.16 for licensed bands to enable the operation of relay stations. Subscriber station specifications are not changed."

Since subscriber stations/mobile stations (MS) are not to be changed for multi-hop relay operation, there are two possible solutions for the frame transmitted by the relay station (RS):

The RS looks like a base station (BS) to an MS, which means that the RS allocates resources for an MS (does scheduling) and generates the frame header, including the MAP messages. For convenience, this type of RS is referred to as a "Type I" RS in this document.

The RS is transparent to an MS, which means that the RS does not allocate resources for an MS or generate the frame header. Instead, an upstream station (BS or RS) performs these functions and the RS either transmits the same frame header (preamble and MAP messages) as the upstream station or does not transmit the frame header at all. When the RS does not transmit the frame header, the MS receives data from the RS and only receives the frame header from the upstream scheduling station. This type of RS is referred to as a "Type II" RS in this document.

The complexity and capability, as well as the cost, of various types of RSs are different. A flexible multi-hop frame structure is necessary to accommodate the different types of RSs.

2 Proposed relay system topology

A topology diagram of a network including RSs is given in the IEEE 802.16j usage model document [2]. However, there is no distinction between different types of RSs in this diagram. As stated above, a Type-II RS does not generate MAP messages for the MSs associated with it. It is not efficient to have multiple Type-II RSs in cascade since the scheduling has to be done by a Type-I RS at the top level. Based on the above reasons, we propose that a Type-II RSs can not cascade a Type-I RS, e.g., no Type-I RS can be downstream from a Type-II RS. The proposed relay system topology is shown in Figure 1.

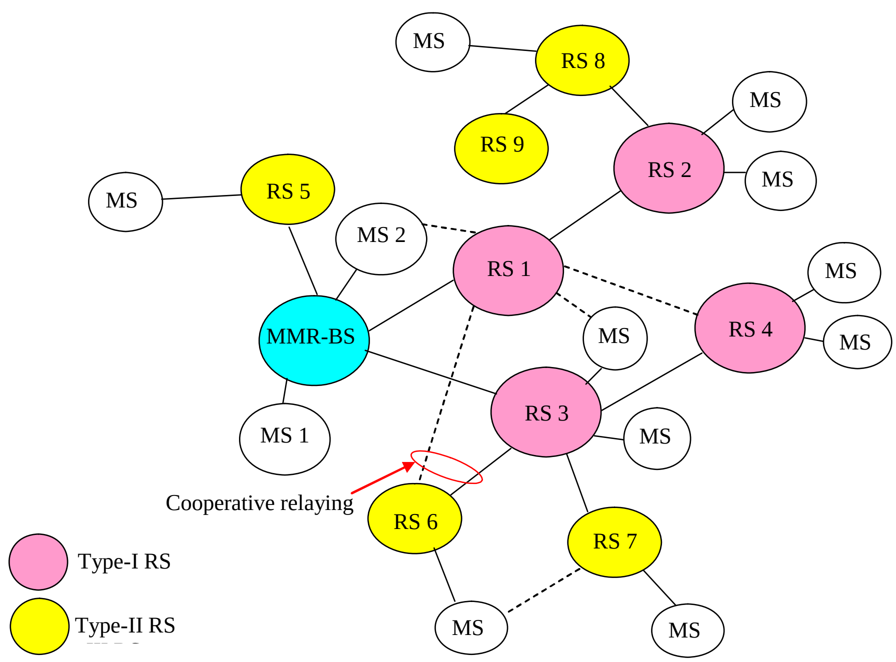

Figure 1: Proposed relay system topology

3 Proposed multi-hop frame structure

3.1 Proposed multi-hop frame structure framework

Based on the above system topology, we proposed a flexible multi-hop TDD frame structure as shown in Figure 2. The whole PMP frame is divided in time into six parts, which are:

- Access downlink (ADL)
- Access uplink (AUL):
- Downlink relay zone (DRZ)
- Uplink relay zone (URZ)
- First bi-directional relay zone (FBRZ)
- Second bi-directional relay zone (SBRZ).

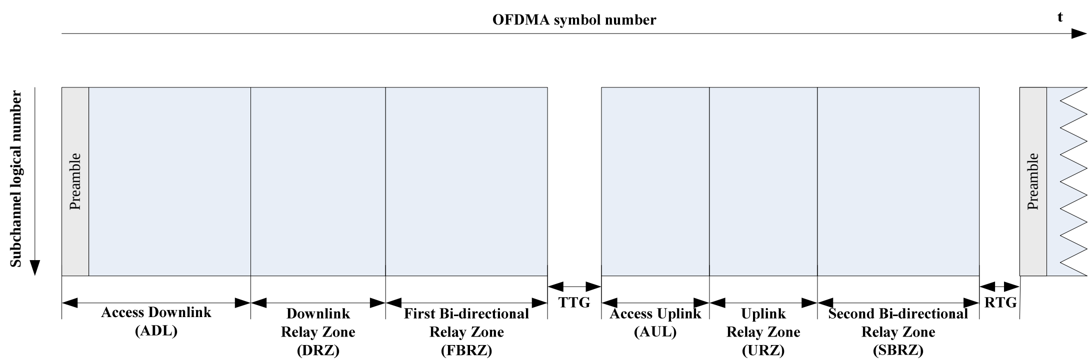

Figure 2: Proposed multi-hop frame structure

The different parts of the frame are used as follows:

- The ADL and AUL are used for MS access links.
- The DRZ and URZ are used for the relay link between a Type-II RS and either an MMR-BS or a Type-I RS.
- The FBRZ and SBRZ are used for the relay link between a Type-I RS and either an MMR-BS or another Type-I RS.

To comply with the restriction against changes to the MS specification, the structure of ADL/AUL is the same as the 802.16e PMP DL/UL subframe except that the length of the ADL/AUL is shorter. The transition between the ADL and the DRZ is indicated in the DL-MAP by a TD_Zone_IE. The transition between the AUL and the URZ is indicated in the UL-MAP by a UL_Zone_IE.

3.2 Type-I RS

According to the proposed relay system topology, Type-I RSs can be cascaded to extend the coverage. In this subsection, we will illustrate how this is done using the frame structure shown in Figure 2. In this example, a three-hop relay system topology is considered, as shown in Figure 3, where both RS1 and RS2 are Type-I RSs. For this topology, the corresponding frame structure is shown in Figure 4.

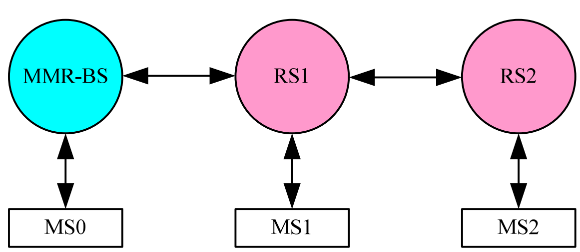

Figure 3: Example topology

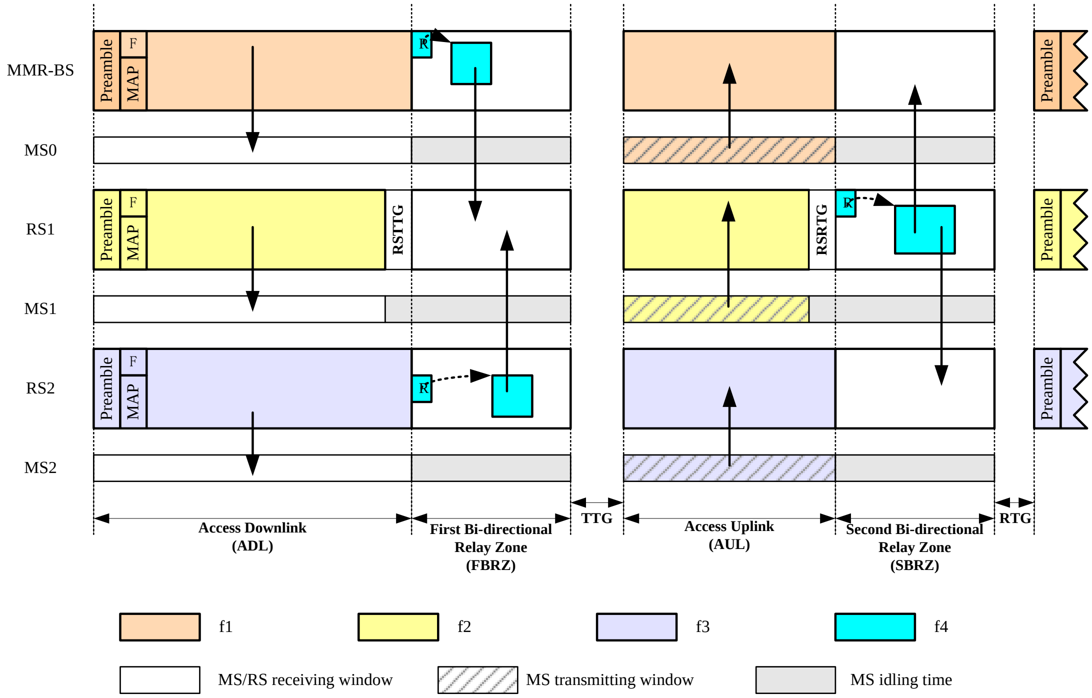

Figure 4: Example frame structure for multi-hop cascade

The MMR-BS and the two RSs are operating in different RF channels or in different segments or subcarriers of the same RF channel in the ADL and AUL to avoid interference. However, frequency reuse is possible in the access link when two stations are geographically separated.

Since there is no Type-II RS in this topology, DRZ and URZ do not exist in the frame structure.

The two bi-directional relay zones (BRZ) are used for multi-hop cascade. Each station (MMR-BS or Type-I RS) transmits in its designated resource block in one BRZ and receives in the other BRZ. In each BRZ, the transceiver states of two adjacent stations are opposite. Both the transmission and reception in each BRZ can be bi-directional, which means that an RS may transmit in the upstream and downstream directions at the same time. For an intermediate RS, the data directed to both the upstream station and the downstream stations can be encoded in one data burst and transmitted in the transmitting BRZ of the RS. Similarly, the RS can receive from both the upstream station and the downstream stations in the receiving BRZ.

The use of the bi-directional relay zones has the following advantages over the use of separated downstream and upstream zones.

- It reduces the transceiver status transition time.
- The similarity between relay-uplink and relay-downlink radio channels may be exploited, which possibly allows for more efficient transmission of control information for data bursts.
- It gives freedom to the scheduler to further improve the throughput of a relay link, e.g., the combination of downlink and uplink has better tolerance to dynamic traffic.

For a Type I RS, FBRZ/SBRZ is used to support multi-hop relaying. The multi-hop cascade is fulfilled by changing the transceiver status of FBRZ/SBRZ. For a RS, the transceiver status during the FBRZ/SBRZ is the opposite of its superior node and subordinate nodes. So, the RS can receive a data burst from its superior node and subordinate nodes at the same time, or it can transmit a data burst to its superior node and subordinate nodes at the same time.

In the FBRZ/SBRZ, RFCH (Relay Frame Control Header) is fixed at the beginning of BRZ. RFCH is used as a pointer to the position of self-managed resource which is used for the transmission of relayed data burst. The data burst parameters are indicated by the R-MAP, which is located at the beginning of the self-managed resource. In summary:

- A Relay Frame Control Header (RFCH) points to a self-managed resource, RFCH may includes the RS_CID, location information of self-managed resource, etc.;
- A self-managed resource block consists of one R-MAP and several data burst, which are transmitted by a single RS. A self-managed resource block can be allocated to a RS by the MMR-BS after the network entry or upon

request by the RS;

- A self-managed resource block begins with a R-MAP, which is like a combination of UL-MAP and DL-MAP. The R-MAP may include parameters of the transmitted data bursts, such as the receiver RS_CID, etc..
- Relay uplink and downlink data can be multiplexed in the same burst or separated in different bursts according to the channel quality of relay uplink and downlink;
- Each RS uses its own RFCH and self-managed resource; however, frequency reuse can be adopted according to the spatial separation.

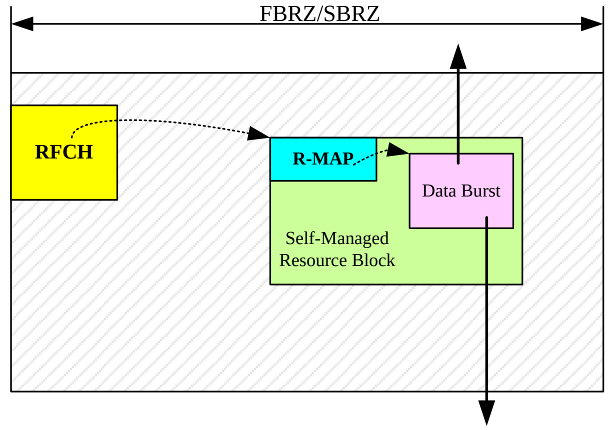

Figure 5 Example of zoomed BRZ

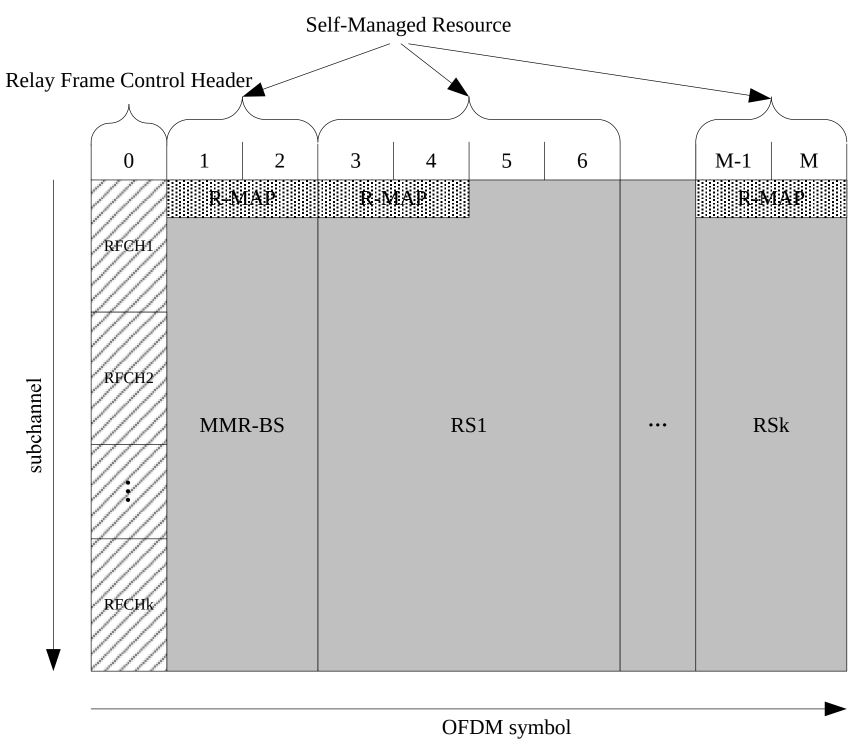

Figure 6 Accommodation of multiple RSs in the BRZ

3.3 Type-II RS

In this subsection, we will give some examples to show how Type-II RSs are included in the relay network. For Type-II RS, multi-hop cascade via DRZ/URZ is optional. However, Type-II RS can only cascade Type-II RS.

The scheduling for both the access link and relay link of a Type-II RS is done by the AS. The Type-II RS can transmit the same frame header as its AS in order to extension the coverage, or simply does not transmit the frame header at all.

The topology shown in Figure 7 is considered, where:

- Access Station (AS) is an MMR-BS or Type-I RS
- RS1 is a Type-II RS that does not transmit the frame header

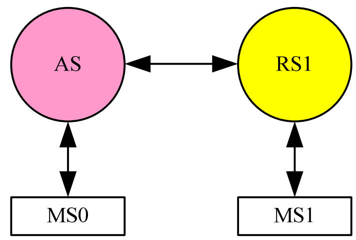

Figure 7: Example topology for Type-II RS

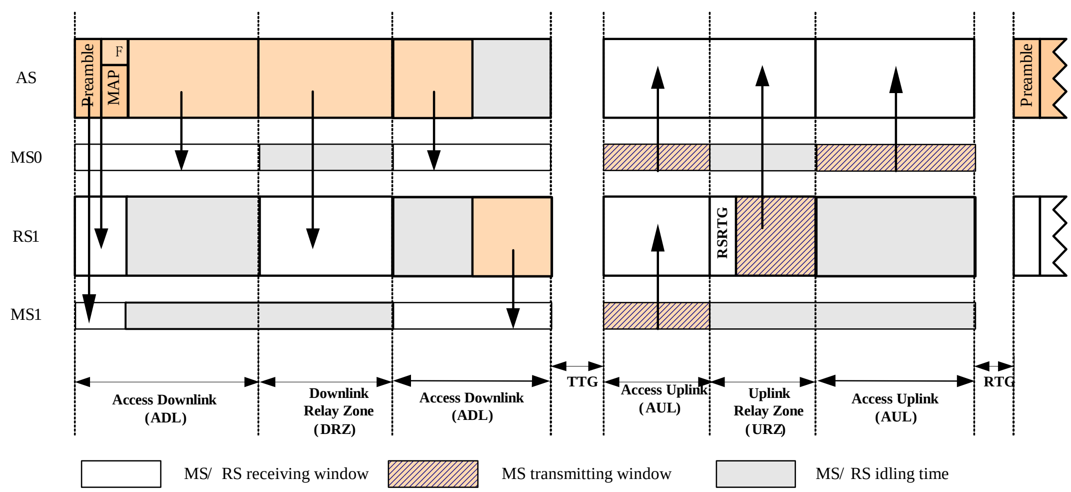

Figure 8: Example frame structure for the case that RS does not transmit the frame header

A Type-II RS uses the same subcarriers as it's AS in the access link (i.e., ADL and AUL). However, they use different time slots in the ADL when serving MSs to avoid pilot collision.

RS1 does not generate and transmit a frame header (preamble, FCH, MAP). RS1 and the MSs synchronize to the AS and also get the MAP messages directly from the AS. RS1 generates a data burst in the ADL according to the MAP messages it receives from the AS in the same frame. These messages may be obtained either from an optional R-MAP included in the relay zone or from the MAP at the beginning of the frame. The data received in the relay zone may be scheduled for transmission in the current frame, or if the RS is not capable of constructing the burst in time, the data will be scheduled for transmission in the next frame. If an RS does not have the capability to generate a data burst in the same frame where it receives the MAP, the AS should provide the MAP information to the RS together with the associated burst in the previous frame.

The topology shown in Figure 9 which enables multi-hop cascade is considered, where:

- Access Station (AS) is an MMR-BS or Type-I RS
- RS1/RS2 is a Type-II RS that transmits the same frame header as the AS

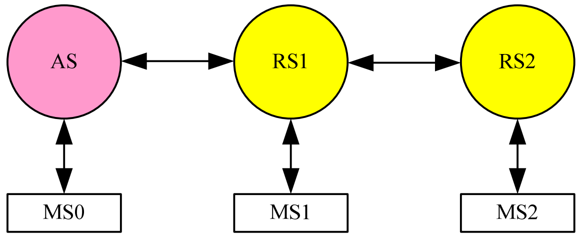

Figure 9: Example multi-hop topology for Type-II RS

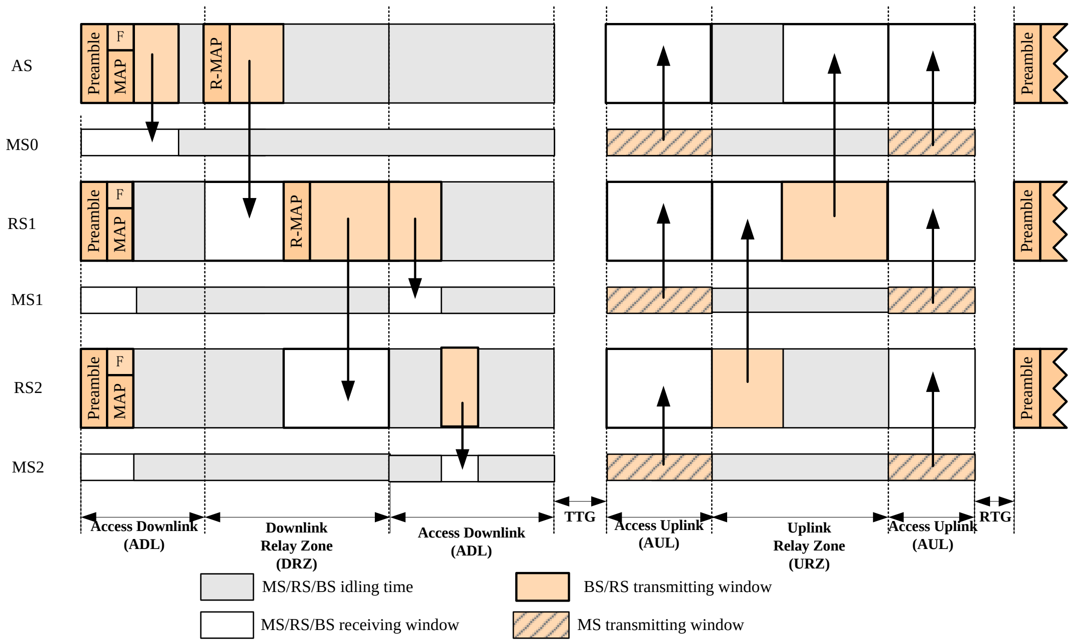

Figure 10: Example frame structure for the case that RS transmit the same frame header

RS1/RS2 transmits the same preamble and MAP messages as it's AS. Therefore, the MAP messages should be received in the previous frame, along with the burst data. R-MAP indicates the resource allocation for RS link. These messages can be from R-MAP or other management messages. Data received by RS may be forwarded within the same frame or the next frame, depending on the RS processing capability and resource status.

The signal received by an MS is a superposition of the Type-II RS and the AS transmissions. Since there is no interference, the MS can decode the MAP messages to know where to receive its data and where to transmit its data without any awareness that the data burst was transmitted by an RS.

For both the DRZ and the URZ, the scheduling is done by the AS of the Type-II RS. The DRZ begins with an R-MAP message, which consists of an RDL-MAP and an RUL-MAP. RDL-MAP gives control information for relay downlink transmission in the DRZ, and RUL-MAP for relay uplink transmission in the URZ. FBRZ and SBRZ are not used for Type-II RSs.

For a Type II RS, DRZ/URZ is used to fulfill the relayed data transmission, and optional multi-hop cascade. The scheduling for both the access link and relay link of a Type-II RS is done by the AS. The Type-II RS can transmit the same frame header as it's AS in order to extend coverage, or may not transmit the frame header at all.

An RS preamble and R-MAP may be optionally located at the beginning of the relay zone for subordinate RS synchronization and resource allocation. However, for the relay system where the RS does not transmit the frame header, the RS may achieve synchronization and get resource allocation information from the BS frame header directly so the RS preamble and R-MAP are not necessary.

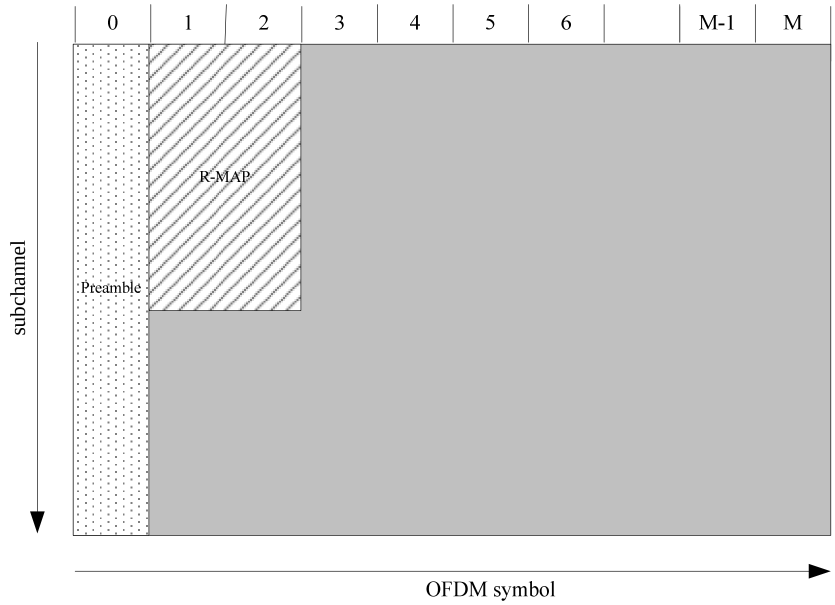

Figure 11 Example of DRZ

For a Type-II RS, one ranging channel located in the AUL is shared by all MSs within its serving station. It is allocated by the serving station, and all MSs within the serving station shall use this ranging channel to transmit CDMA initial ranging, periodic CDMA ranging, and contention-based bandwidth request. All Type-II RSs controlled by the same serving station shall also use this ranging channel for network entry and initialization.

3.4 Incorporation of all types of RSs

In a system where all types of RSs co-exist, the DRZ/URZ as well as the FBRZ/SBRZ should be used.

4 Text Proposal

[Insert the following text into section 8.4.4.8]

8.4.4.8 Relaying frame structure

In TDD system, the whole PMP frame is divided in time into six parts in order to support the multi-hop relaying, which are:

- Access downlink (ADL)
- Access uplink (AUL):
- Downlink relay zone (DRZ)
- Uplink relay zone (URZ)
- First bi-directional relay zone (FBRZ)
- Second bi-directional relay zone (SBRZ).

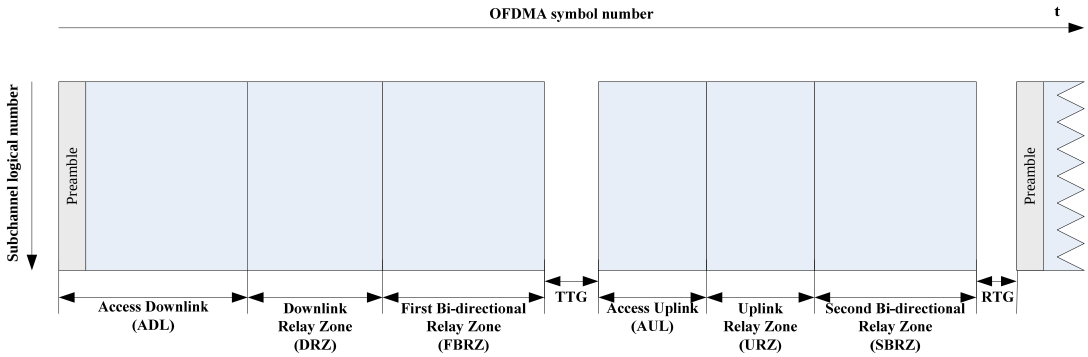

Figure 12: Example of multi-hop frame structure

The different parts of the frame are used as follows:

- The ADL and AUL are used for MS access links.
- The DRZ and URZ are used for the relay link between a Type-II RS and either an MMR-BS or a Type-I RS.
- The FBRZ and SBRZ are used for the relay link between a Type-I RS and either an MMR-BS or another Type-I RS.

To comply with the restriction against changes to the MS specification, the structure of ADL/AUL is the same as the 802.16e PMP DL/UL subframe that the length of the ADL/AUL is shorter. The transition between the ADL and the DRZ is indicated in the DL-MAP by a TD_Zone_IE. The transition between the AUL and the URZ is indicated in the UL-MAP by a UL_Zone_IE. There are two type of relay zone defined, a relay station can support any one or both relay zone according to its capability.

[Insert the following text into section 8.4.4.8.1]

8.4.4.8.1 Relay zone for Type-I RS

For a high capability relay station, FBRZ/SBRZ is used to support multi-hop relaying. The multi-hop cascade is fulfilled by changing the transceiver status of FBRZ/SBRZ. For a RS, the transceiver status during the FBRZ/SBRZ is the opposite of its superior node and subordinate nodes. So, the RS can receive a data burst from its superior node and subordinate nodes at the same time, or it can transmit a data burst to its superior node and subordinate nodes at the same time.

In the FBRZ/SBRZ, RFCH (Relay Frame Control Header) is fixed at the beginning of BRZ. RFCH is used as a pointer to the position of self-managed resource which is used for the transmission of relayed data burst. The data burst parameters are indicated by the R-MAP, which is located at the beginning of the self-managed resource. In summary:

- A Relay Frame Control Header (RFCH) points to a self-managed resource, RFCH may includes the RS_CID, location information of self-managed resource, etc.;
- A self-managed resource block consists of one R-MAP and several data burst, which are transmitted by a single RS. A self-managed resource block can be allocated to a RS by the MMR-BS after the network entry or upon request by the RS;
- A self-managed resource block begins with a R-MAP, which is like a combination of UL-MAP and DL-MAP. The R-MAP may include parameters of the transmitted data bursts, such as the receiver RS_CID, etc..
- Relay uplink and downlink data can be multiplexed in the same burst or separated in different bursts according to the channel quality of relay uplink and downlink;
- Each RS uses its own RFCH and self-managed resource; however, frequency reuse can be adopted according to the spatial separation.

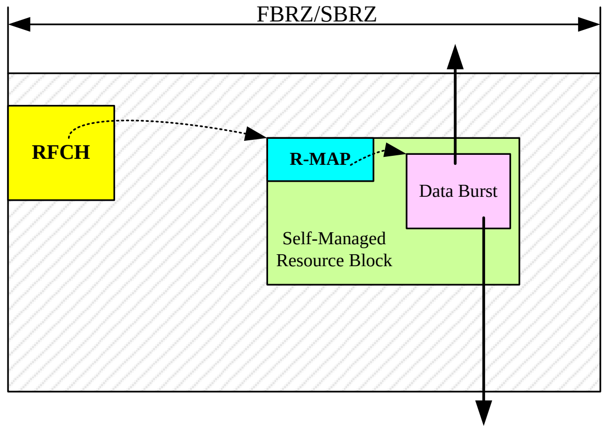

Figure 13 Example of zoomed BRZ

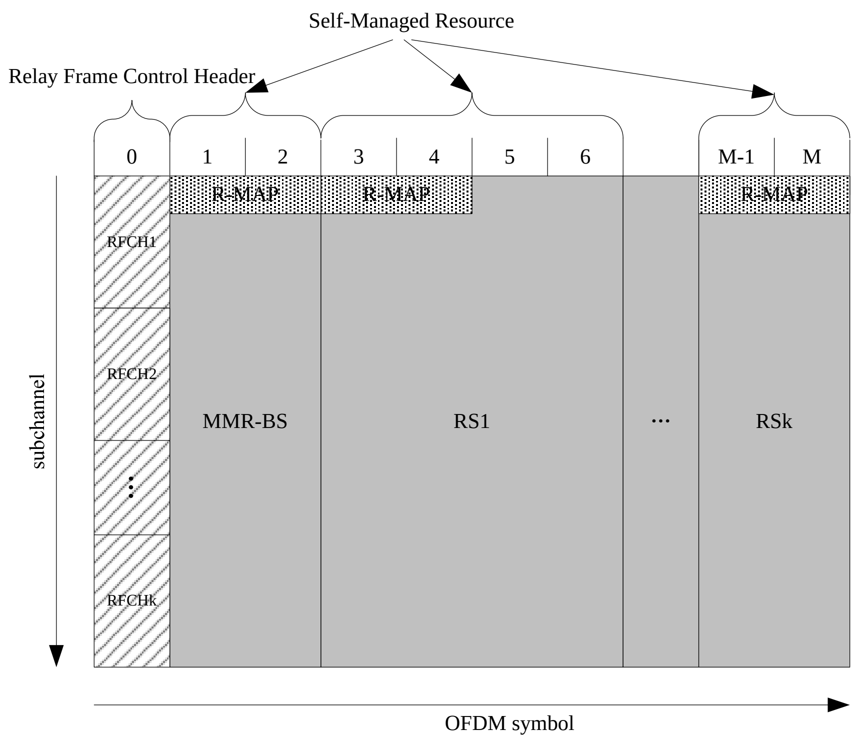

Figure 14 Accommodation of multiple RSs in the BRZ

[Insert the following text into section 8.4.4.8.2]

8.4.4.8.2 Relay zone for Type-II RS

For a low capability RS, DRZ/URZ is used to fulfill the relayed data transmission, and optional multi-hop cascade. The scheduling for both the access link and relay link of a Type-II RS is done by the AS. The Type-II RS can transmit the same frame header as it's AS in order to extend coverage, or may not transmit the frame header at all.

An RS preamble and R-MAP may be optionally located at the beginning of the relay zone for subordinate RS synchronization and resource allocation. However, for the relay system where the RS does not transmit the frame header, the RS may achieve synchronization and get resource allocation information from the BS frame header directly so the RS preamble and R-MAP are not necessary.

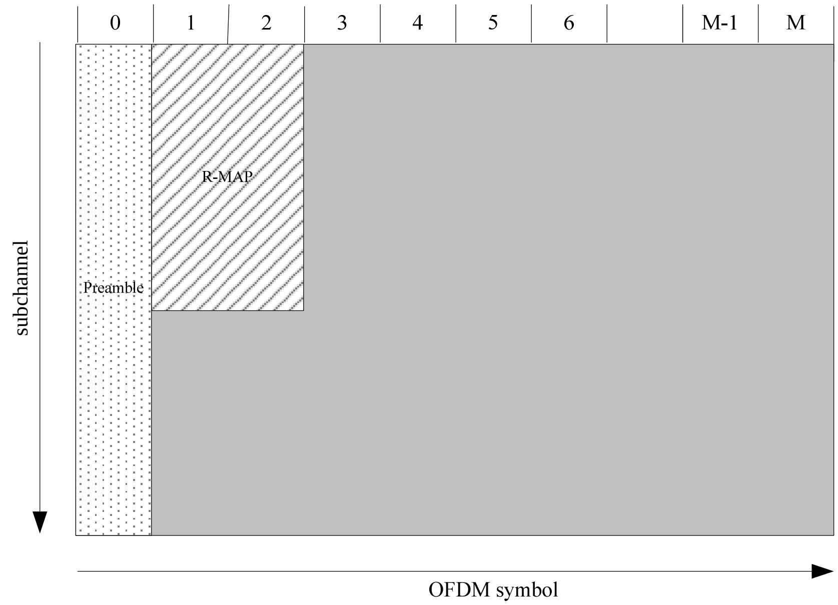

Figure 15 Example of DRZ

For a Type-II RS, one ranging channel located in the AUL is shared by all MSs within its serving station. It is allocated by the serving station, and all MSs within the serving station shall use this ranging channel to transmit CDMA initial ranging, periodic CDMA ranging, and contention-based bandwidth request. All Type-II RSs controlled by the same serving station shall also use this ranging channel for network entry and initialization.

[Insert the following text into section 8.4.5]

8.4.5 Map message fields and IEs

R-MAP indicates the resource allocation information to each transmitted burst. R-MAP is consisted of a number R-MAP-IE, which includes the RS_CID and burst parameters.

5 References

[1] 802.16j PAR.

[2] Jerry Sydir, et. al., Harmonized Contribution on 802.16j (Mobile Multihop Relay) Usage Models, IEEE 802.16j-06/015.