Project	IEEE 802.16 Broadband Wireless Access Working Group <**http://ieee802.org/16**>
Title	Multi-phase Frame Structure Proposal
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Re:	Call for Technical Proposals (IEEE 802.16j-06/027)
Abstract	We propose a multi-phase frame structure for the relay link. This multi-phase frame structure reduces interference by dividing RSs into groups associated with the phases. During a phase, only one group can transmit. This reduces interference by reducing the number of simultaneously transmissions. Our frame structure does not limit the number of RSs deployed or the number of hops between the MR-BS and MSs.
Purpose	This contribution is submitted for discussion and adoption in 802.16j.
Notice	
Release	
Patent Policy and Procedures	

Multi-phase Frame Structure Proposal

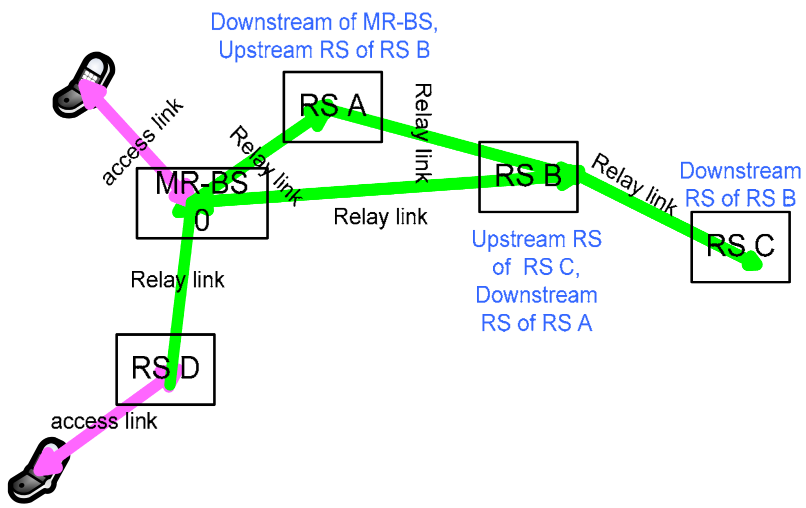
Terminology

MR-BS = MR base station
RS = relay station
MS = mobile subscriber station
IS = infrastructure station (MR-BS or RS)

Introduction

An example MR network topology is shown in Figure 1. MR networks contain two types of links. Links between the MR-BS and RS and between RSs are referred to as relay links, while links between the MR-BS and MS and between the RS and MS are referred to as access links. The frame structure for MR networks should support a flexible sharing of radio resources between the relay and access links. It should support the case of "in-band relay" where a given channel (frequency allocation) is shared between some number of relay and access links. It should also support the case of "out-of-band relay" where different channels (frequencies) are assigned to access links and relay links. In both of these cases, the frame structure should support the usage of a channel by multiple relay links across multiple hops (for example the relay links between MR-BS, RS A, RS B, and RS C). The frame structure should also support topologies with multiple paths between the MR-BS and an MS, and should allow the operator to control the level of interference between the stations sharing a channel by partitioning the radio resources to match the requirements of specific deployments.

Figure 1.An example MR topology



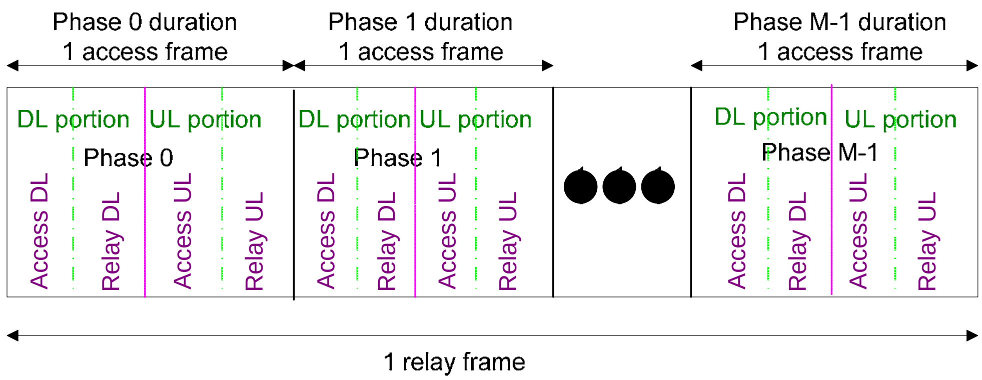
We propose the frame structure depicted in Figure 2. This frame structure supports both in-band and out-of-band relay. The figure shows the in-band relay case. See section 4 for a description of relay frame for the out-of-band relay case

For both in-band and out-of-band relay,

1. The relay frame is composed of a number of phases; this number is configurable.
2. Each phase is divided into a DL and UL portion.

3. The boundary between the DL and UL portions of a phase is configurable

Figure 2.Multi-phase frame structure



In-band multi-phase frame structure

In the case of in-band relay:
1) The size of a phase must be the length of an access frame. From the perspective of the access links, each phase of the relay frame constitutes an access frame.

2) The DL portion of each phase is further split into an Access DL zone and a Relay DL zone (and the UL portion is divided into Access and Relay UL zones). The detailed makeup of a phase is illustrated in Figure 3. The Access DL begins with a preamble as specified in 802.16e. The structure of the FCH and DL-MAPs within the Access DL is also as specified in 802.16e. There is a gap (labeled Relay TTG) between the Access DL and Relay DL. This gap allows an infrastructure station which transmits in the Access DL and receives in the Relay DL to transition from transmit to receive mode (unnecessary for stations not transitioning). The Relay DL also contains a midamble, FCH and maps. The preamble is shown in the figure. Between the Relay DL and Access UL is the RTG. Between the Access UL and Relay UL is the Relay RTG (unnecessary for infrastructure stations not transitioning). Finally between this phase and the next phase (or next frame if this is the last phase in the frame) is the RTG.

3) **All** ISs transmit a preamble at the start of the Access DL zone and have permission to schedule access DL/UL transmissions during the Access DL/UL zones of each phase; MSs associated with an IS receive from the IS in the Access DL and transmit to the IS in the Access UL.

4) **A subset** of ISs are assigned to transmit a preamble at the start of the Relay DL zone and have permission to schedule relay DL/UL transmissions on the Relay DL/.UL zones of each phase, These ISs transmit in the Relay DL of a phase and are referred to as upstream stations within that phase.

5) An IS can be assigned to be an upstream station in **more than one** phase;

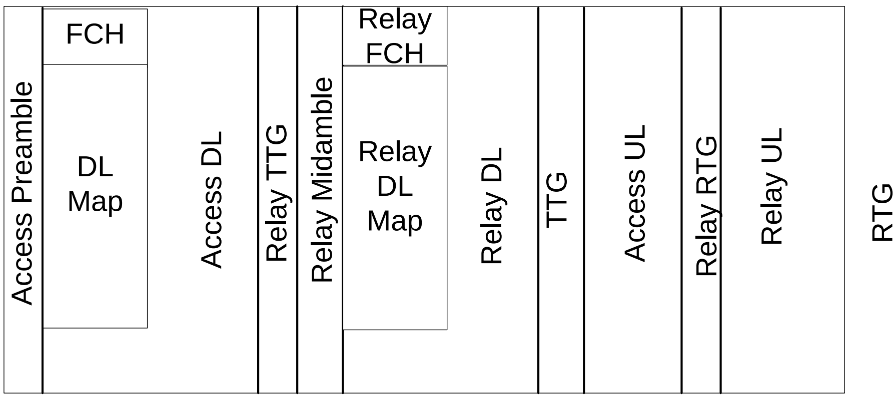
6) A subset of ISs are assigned to receive in the Relay DL of each phase and to transmit in the Relay UL. An IS that is assigned to receive in the Relay DL of a phase is referred to as a downstream station within that phase.

7) An IS can be assigned to be a downstream station in **more than one** phase;

8) The Relay DL and Relay UL zones can be further split along the time axis into distinct scheduling areas that are assigned to different groups of stations already assigned to the zone in order to isolate data transmissions from interference. Finally, both Access and Relay zones can be split along the frequency dimension using PUSC segments.

9) An IS can be given permission to schedule Access DL/UL transmissions during the Relay DL/UL zones of one or more phases if the IS is not a downstream station in those phases.

Figure 3.Structure of a phase – in-band configuration



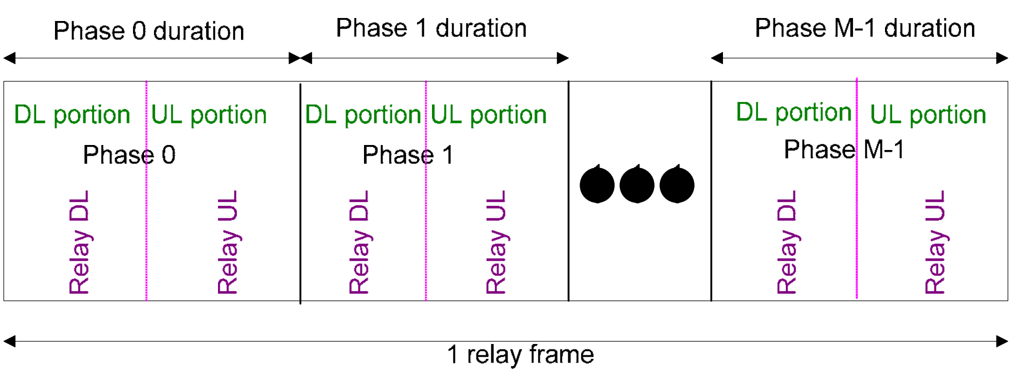
Permission to schedule during the Relay DL and UL zones of a given phase is assigned on a per "bi-directional link" basis. In other words, when a bi-directional link is assigned to the relay zones of a phase, that link's upstream station transmits/receives during the relay DL/UL, while that link's downstream station receives/transmits during the relay DL/UL. Within a phase, an IS can be an upstream station (i.e. transmits/receives during the relay DL/UL), a downstream station (i.e. receives/transmits during the relay DL/UL), or neither. An IS cannot be assigned to be both an upstream and a downstream station within a phase. This implies that two consecutive links in a path cannot be included in the relay zones of the same phase.

Out-of-band multi-phase relay frame structure

The out-of-band configuration of the proposed frame structure is shown in Figure 4. In the case of out-of-band relay:

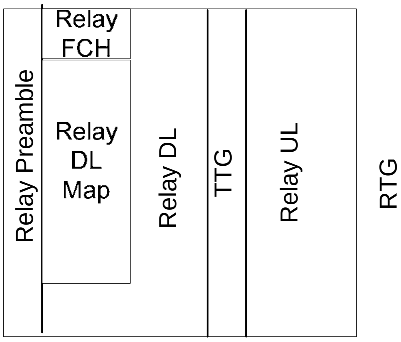
1. The phase length is configurable.
2. The DL and UL portions of each phase contain only relay zones. (The Access DL and Access UL are omitted).
3. ISs are assigned to be upstream and downstream stations within phases in the same way as in the in-band configuration.

Figure 4.Out-of-band multi-phase relay frame structure



The structure of a phase in the out-of-band configuration is illustrated in Figure 5.

Figure 5.Structure of a phase – out-of-band configuration



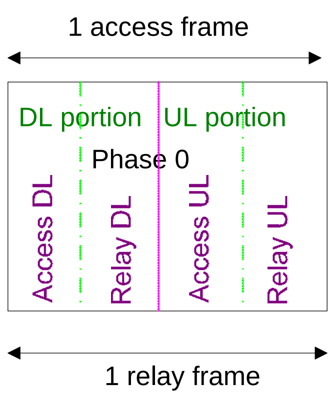
Common Frame Structure Configurations

In this section we describe some of the frame structure configurations that may be used in deployments. These configurations are provided as examples to illustrate the use of the proposed configurable frame structure. These configurations are only examples and other configurations are possible and are not precluded by the proposed frame structure.

In-Band Frame Configuration for 2 hop network

In this case the topology is limited to two hops. The first hop spans from the MR-BS to the RSs and the second hop spans from the RSs to the MSs. Figure 6 shows the frame structure configuration for this case. One phase is sufficient to support the PMP link between the MR-BS and RSs, so the frame structure is configured to have one phase and the relay frame duration corresponds to the access frame duration. The MR-BS and RSs transmit to MSs in the Access DL and receive from the MSs in the Access UL. The MR-BS transmits to the RSs in the Relay DL and receives from the RSs in the Relay UL. Finally, the RSs receive from the MR-BS in the Relay DL and transmit to the MR-BS in the Relay UL.

Figure 6.In-band Frame structure for 2-hop only network



In-band Frame Configuration for Multi-hop network

In order to support communications across more than two hops (i.e. more than one hop of relay links), at least two relay phases are required. The frame structure configuration illustrated in Figure 7 has two phases, which are labeled Odd and Even. All ISs transmit a preamble at the start of the Access DL zone of each phase and have permission to schedule Access DL/UL transmissions during the Access DL/UL zones of each phase. RSs that are an odd number of hops from the MR-BS are assigned to be upstream stations in the odd phase and to be downstream stations in the even phase. The MR-BS and RSs that are an even number of hops away from the MR-BS are assigned to be upstream stations in the even phase and downstream stations in the odd phase.

In this topology the duration of the relay frame is twice that of the access frame. A common configuration is expected to be a 5 ms access frame duration and a 10 ms relay frame duration.

Figure 7.Two phase relay frame structure for in-band multi-hop

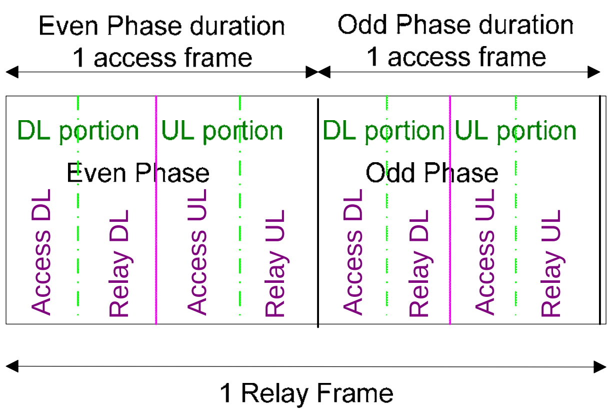
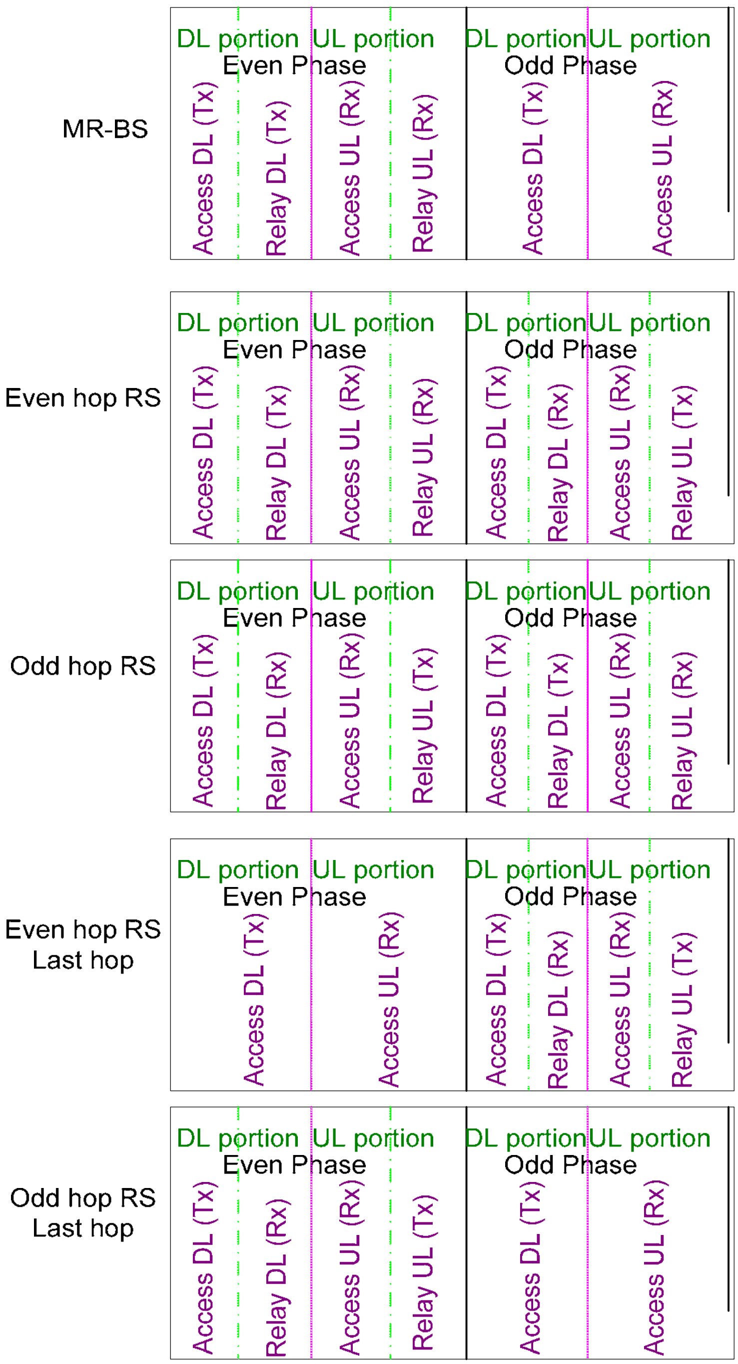


Figure 8 shows the frame structure from the perspective of the MR-BS, even hop RS, odd hop RS, even hop RS at the end of the chain, and odd hop RS at the end of the chain. The figure illustrates how the stations at the end of the chain utilize the Relay DL and UL zones in which they do not participate for access link transmissions and identifies which stations are transmitting and which are receiving in each of the zones. Note that an IS could potentially use the Relay DL and UL zones in which it participates as an upstream station for access traffic as well. However, since this depends on proper interference and traffic load conditions, it is not depicted in Fig. 8.

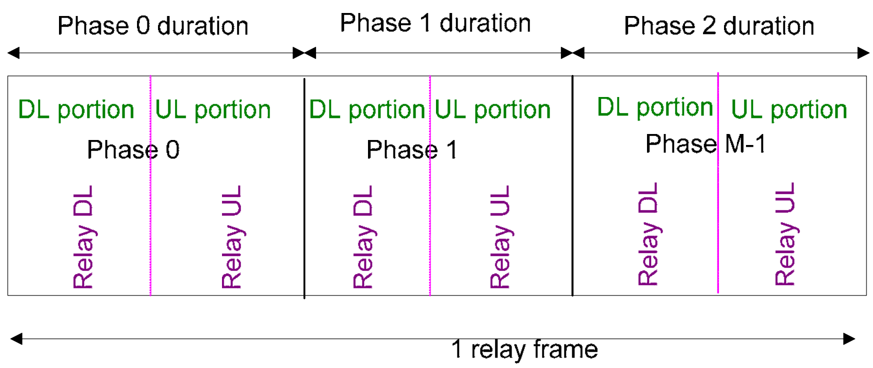
Figure 8.Two phase relay frame structure for in-band multi-hop from perspective of different stations



Out-of-Band Multi-phase Structure

For out-of-band relay, the number of relay phases can be selected to provide more control over interference and to support topologies with multiple paths between the MR-BS and MS (not a pure tree topology). See section 7 for some of the arguments for supporting more than two phases. In Figure 9 we show a three phase frame structure. Three phases can be supported in a 5 ms frame. Configurations that use more than three phases are also possible, but the length of the relay frame needs to be longer than 5 ms.

Figure 9.Out-of-band three-phase relay frame structure



Frame Overhead and Latency Analysis

Each phase has some associated overhead. Specifically this overhead consists of a preamble, FCH, common portions of the DL and UL MAP and 2 Rx/Tx (and Tx/Rx) gaps. We estimate this to be about 6% per phase in the worst case. Given this overhead, the practical limit on the number of phases that can be supported is 3 phases for an out-of-band 5 ms relay frame (as illustrated in Figure 9) and 2 phases for an in-band 10 ms relay frame (as illustrated in Figure 7).

The latency incurred by a packet is a function of the number of hops. In general the latency incurred by a packet at each hop is <= relay frame duration. In the two phase configuration, the latency incurred per hop is ½ the relay frame duration. In configurations with more than two phases, the latency per hop can be as short as a phase duration and as long as the relay frame duration.

Reasons to Use More than Two Phases

Interference

When multiple infrastructure stations transmit in the same phase, they can cause interference with other stations. Even if we use PUSC segments to divide the phases into 3 partitions and assign the RSs to individual segments within a phase, stations are assigned to transmit in the same phase and in the same segment can cause significant interference with each other. These stations will interfere with each other, particularly in the transmission of broadcast messages such as the DL-MAP. Dividing the frame into more than two phases allows the RSs to be spread out over a larger number of locations in the frame, reducing the amount of interference.

Support for Multi-path Topologies

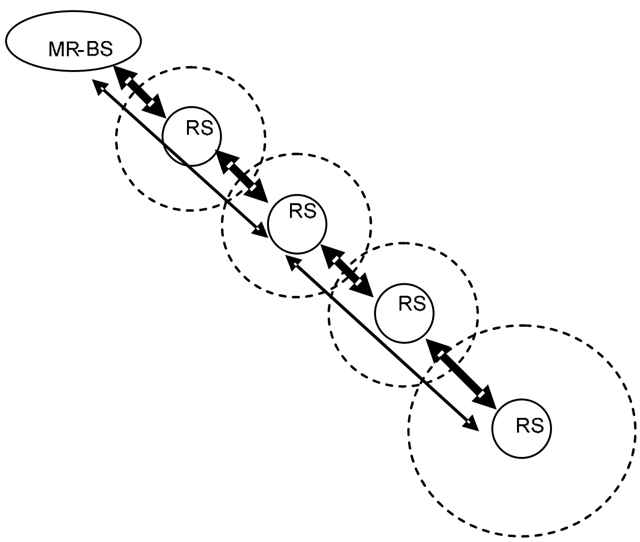
The topology that can be supported with a relay frame configured to include only two phases is limited to be a pure tree. In such a topology there is only one path between the MR-BS and each MS. Allowing topologies with multiple paths is desirable for the following reasons:

- QoS differentiation on multiple paths
- Increased data rate to an RS cell from reuse on multiple paths

QoS differentiation on multiple paths

Figure 10 depicts a case where having multiple paths supports QoS differentiation. Assume that the short links have significantly higher data rate than the long links (their respective thickness indicates the difference in capacity). A provider may choose to incur the added delay of transmitting best effort traffic along the short links in exchange for significantly higher total data rate. That same provider may require voice services to transmit via the long links since they have strict delay and low data rate requirements.

Figure 10.QoS differentiation across multiple paths

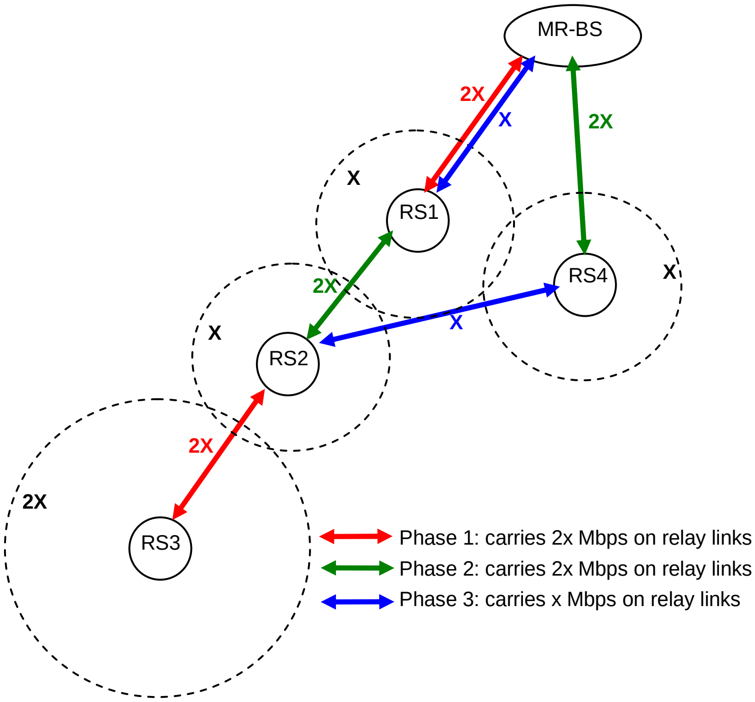


Increased data rate to an RS cell from reuse on multiple paths

Figure 11 depicts a case where the deliverable data rate to an RS cell (i.e. RS3) is increased via reuse on multiple paths. In this example, all relay links transmit on the same "channel instance" and have similar channel quality; however, they share this "channel instance" in TDM fashion via multiple phases. The link color indicates the phase that the relay link transmits/receives on. Phases 1 and 2 are the same length and support 2X Mbps, while Phase 3 is *half* this length and supports X Mbps (i.e. this is an example of varying phase sizes in out-of-band relay). We assume that relay links of the same color can transmit simultaneously.

Small cells require X Mbps, while the large cell requires 2X Mbps. These rate requirements can be supported by reusing the phases on two different paths as depicted in Figure 11. If we remove the right path and merge Phase 3 into Phase 1 (i.e. its length is increased by 50%), then the highest rate we can provide to RS3 is X Mbps.

Figure 11. Increased data rate from reuse on multiple paths



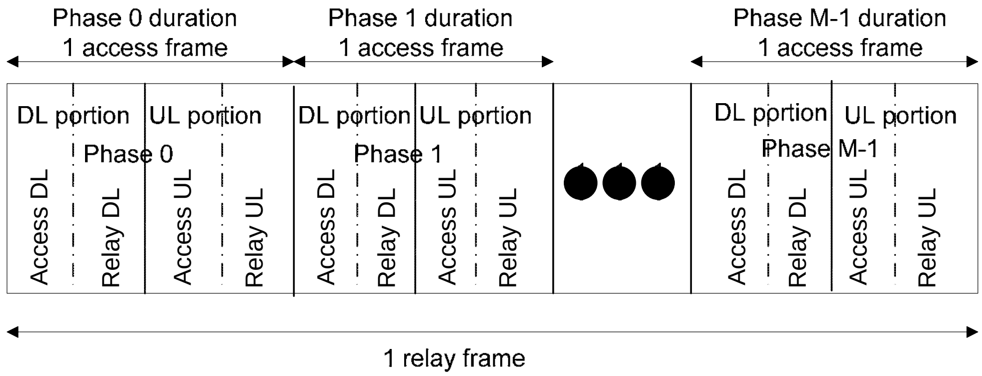
Proposed Text

[Insert the following text into section 8.4.4.8 Frame Structure for Relaying]

8.4.4.8.1 Frame Structure for Multi-hop Relay

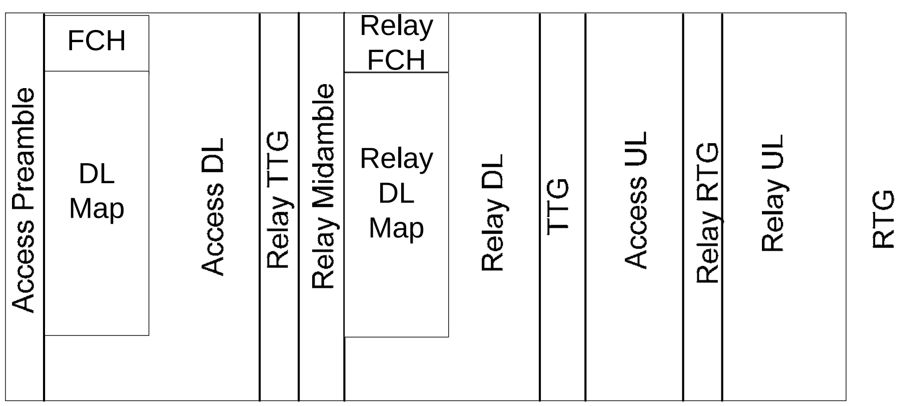
The frame structure for multi-hop relay is shown in figure A. This frame structure supports both in-band and out-of-band relay. The relay frame is composed of a number of phases. The specific number of phases is configurable. Each phase is divided into a DL and UL portion. The boundary between the DL and UL portions of a phase is configurable. The DL portion of each phase is further split into an Access DL zone and a Relay DL zone and the UL portion is divided into Access and Relay UL zones. The Access DL and Access UL are present when the channel is used for in-band relay and are omitted when the channel is used for out-of-band relay.

Figure A .Multi-hop Relay Frame Structure



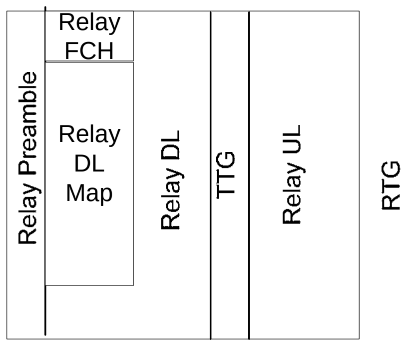
The detailed makeup of a phase used for in-band relay is illustrated in Figure B. The Access DL begins with a preamble. There is a gap (labeled Relay TTG) between the Access DL and Relay DL. This gap allows an infrastructure station which transmits in the Access DL and receives in the Relay DL to transition from transmit to receive mode. The Relay DL also contains a midamble, FCH and maps. The preamble is shown in the figure. Between the Relay DL and Access UL is the RTG. Between the Access UL and Relay UL is the Relay RTG. Finally between this phase and the next phase (or next frame if this is the last phase in the frame) is the RTG. Note that for each gap, if the infrastructure station is not transitioning from TX to RX or vice versa, it can schedule data over the gap.

Figure B. Structure of a phase – in-band configuration



The detailed makeup of a phase used for out-of-band relay is illustrated in Figure C.

Figure C. Structure of a phase – out-of-band configuration



In the case of both in-band and out-of-band relay a subset of ISs are assigned to transmit a preamble at the start of the Relay DL zone and have permission to schedule relay DL/UL transmissions on the Relay DL/.UL zones of each phase. These ISs transmit in the Relay DL, receive in the Relay UL, and are referred to as upstream stations within that phase. An IS can be assigned to be an upstream station in more than one phase.

A subset of ISs are assigned to receive in the Relay DL and transmit in the Relay UL of each phase. These ISs are referred to as the downstream stations within that phase. An IS can be assigned to be a downstream station in more than one phase. Within a phase, an IS can be an upstream station (i.e. transmits/receives during the relay DL/UL), a downstream station (i.e. receives/transmits during the relay DL/UL), or neither. An IS cannot be assigned to be both an upstream and a downstream station within a phase.

In the case of in-band relay, the length of each phase shall equal the length of an access frame. From the perspective of the access links, each phase of the relay frame constitutes an access frame. All ISs transmit a preamble at the start of the Access DL zone and have permission to schedule access DL/UL transmissions during the Access DL/UL zones of each phase. An IS can be given permission to schedule Access DL/UL transmissions during the Relay DL/UL zones of one or more phases if it is not a downstream station in those phases.