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Re:	This is a response to the call for proposals 80216j-06_034.pdf.
Abstract	This contribution propose a frame structure to support multi-hop (>= 2 hops) relay operation.
Purpose	Text proposal for 802.16j Baseline Document.
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Frame Structure to Support Multi-hop Relay Operation

1 Introduction

The frame structure proposal accepted into the working document in the Dallas meeting addresses the case of in-band relay for two hop only networks. It provides a good basis for the frame structure required to support in-band and out-of-band relay in multi-hop networks.

This contribution proposes the additional constructs required to support multi-hop topologies. We define multi-hop topologies to be topologies where the number of hops between the MR-BS and an MS can be 2 hops or larger. Our proposal builds on the configurable frame structure that was defined in the Dallas meeting.

1.1 Support for Multiple Hops

When the topology of an MR network spans more than two hops, some RSs are required to receive from the MR-BS or a parent RS and to transmit to a child RS. In order to support this scenario at least two DL Relay_Zones and two UL Relay_Zones are required to prevent RSs from having to transmit and receive within the same Relay_Zone.

1.2 Support for mobile RS (MRS) handover

In order to support MRS in a multi-hop environment, additional synchronization channels (mid- or post-ambles) are required. A synchronization channel is required for each DL Relay_Zone in order to allow an MRS to synchronize with the DL subframe of a Relay_Zone of a RS or MR-BS. The Frame Start Preamble for the access link cannot be used for this purpose because an RS cannot transmit and receive at the same time. An RS is required to transmit the frame start preamble for its MSs at the start of every frame in order to maintain backwards compatibility. Requiring an MRS to perform synchronization with a RS/MR-BS using this frame start preamble would require that MRS to receive the frame start preambles of the RS/MR-BS while simultaneously transmitting a frame start preamble to its access MS. Hence, a relay preamble that is orthogonal in time to the frame start preamble is needed to support MRS.

1.3 Support for Multiple Frame Sizes

In order to be backwards compatible with 802.16e-2005, 802.16j must support the various frame sizes defined in 802.16e-2005. The smaller of these frame sizes have a limited number of symbols. Because of this, it will be difficult to configure a single frame with multiple Relay_Zones in addition to at least one DL Access zone and one UL access zone. For this reason another mechanism is useful for generating multiple Relay_Zones to be defined while maintaining backwards compatibility for smaller frame sizes.

2 Proposed Solution

The overall approach to supporting multi-hop topologies is to define a super-frame structure that contains multiple Relay_Zones. The MR-BS and RSs can participate in 1 or more Relay_Zones to transmit and receive depending on the deployment scenarios and network assignments. This general structure was suggested in a number of the contributions that were presented at the Dallas meeting. Specifically, we propose the following extensions to the currently specified frame structure to support multi-hop deployments:

- We specify a super-frame structure which allows multiple Relay_Zones to be used for multi-hop communications even when the frame duration is too short to fit all of the Relay_Zones into a single frame.
- DL Relay_Zones contain a relay preamble, which is used by a child RS to synchronize with the DL Relay_Zone of its parent RS or MR-BS. This relay preamble is essential for MRS handover support.
- The R-TTG and R-RTG are renamed to be the R-GAP. The reason is that some RSs will be transmitting in a relay phase and some will be receiving, so the transition between phases is *receive to transmit* for some RSs and *transmit to receive* for others.

2.1 Super-frame

We propose that a super-frame structure depicted in Figure 1 be used to allow for multiple Relay_Zones to be defined, while living within the practical constraints of the number of symbols available in the smaller frame sizes. A super-frame is defined to be a set of consecutive frames. The Relay_Zones within the super-frame are uniquely identified within the super-frame. The number of Relay_Zones within a frame and the number of frames in a super frame are configurable. Only 1 Relay_Zone is depicted in Figure 1 for simplicity even though there can be more Relay_Zones per frame. MR-BS and all RSs shall participate in DL access and UL access zones of every frame within the super-frame structure. However, the MR-BS and RSs can participate in 1 or more Relay_Zones to transmit and receive depending on the deployment scenarios and network assignments. An R-GAP is placed between access and Relay_Zones or between two Relay_Zones which allows stations to switch from receive mode to transmit mode or from transmit mode to receive mode.

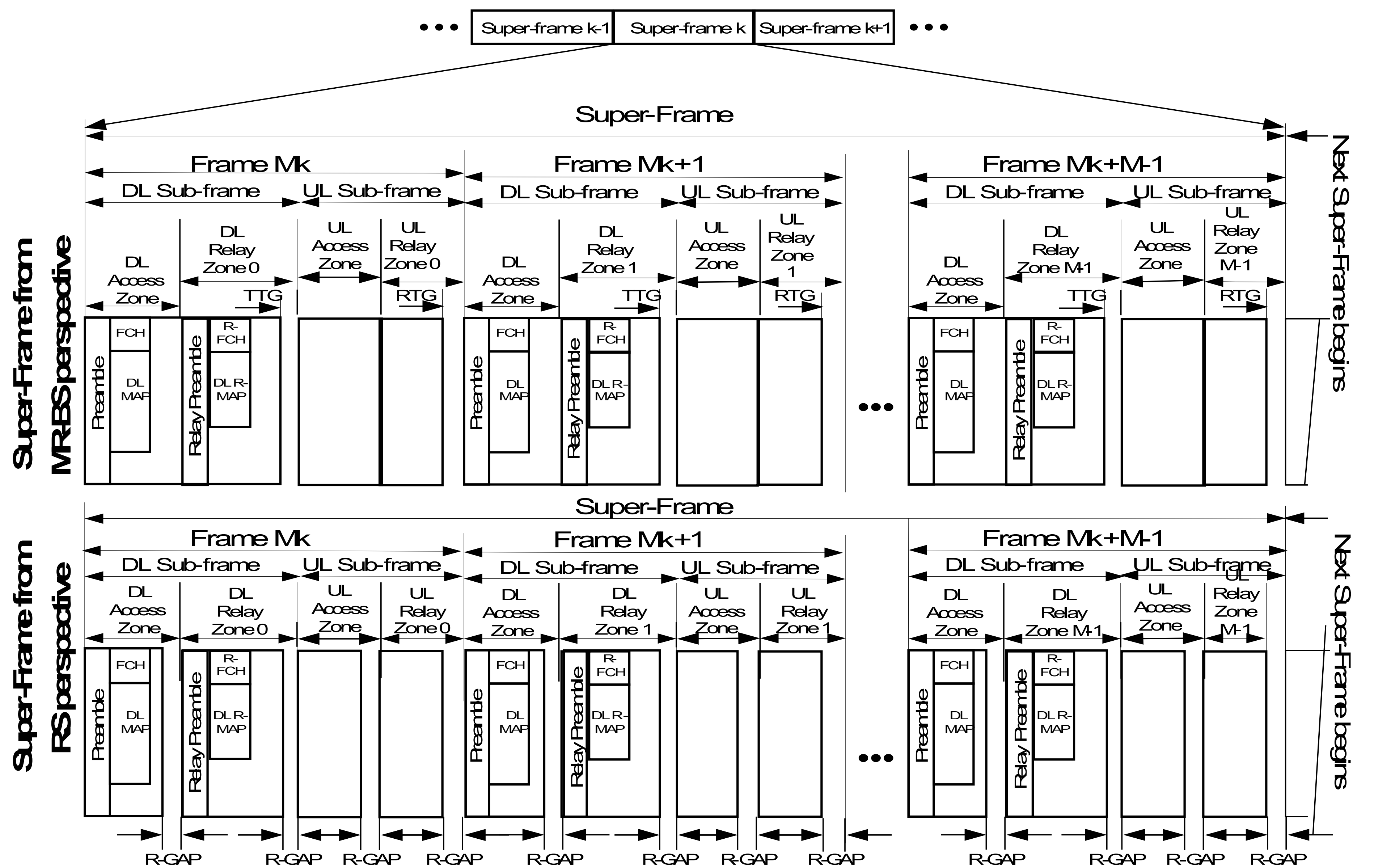
Each frame within a super-frame is divided into a downlink subframe and an uplink subframe. Each downlink subframe contains a DL access zone followed by one or more DL Relay_Zones.

The structure of a DL access zone and a DL Relay_Zone is the same. Each zone begins with a preamble/relay preamble, followed by FCH/R-FCH, DL-MAP/DL R-MAP and an optional UL-MAP/UL R-MAP. During a DL Relay_Zone, an MR-BS may transmit to its child RSs or be idle. Moreover, during a DL Relay_Zone, an RS may, depending on its position in the relaying scenario, either transmit to its child RSs or receive from its parent MR-BS/RS or may be idle.

Each uplink subframe contains a UL access zone followed by one or more UL Relay_Zones. During the UL Relay_Zone of a frame within the super-frame structure, a child RS may, depending on its position in the relaying scenario, transmits to its parent RS or MR-BS or may receive from its child RS. Each frame is expected to contain an equal number of DL and UL Relay_Zones.

If M=1, our super-frame structure defaults back to the frame structure for 2-hop only network. Hence, our super-frame structure is flexible and can be used for 2-hop only or longer hop networks by suitably adjusting the value of M.

Figure 1. k^{th} Super-Frame structure from MR-BS and RSs perspective



2.2 Super-frame structure example with M=2

If M=2 and allowing only 1 Relay Zone per frame, the proposed design will yield a 2 frame super-frame structure depicted in Figure 2 with 1 DL/UL Relay_Zone per frame. As an example, the MR-BS could be assigned to transmit in the DL Relay_Zone in frame 0 and to receive in the UL Relay_Zone in frame 0. The MR-BS could be assigned to be idle in the Relay_Zones in frame 1.

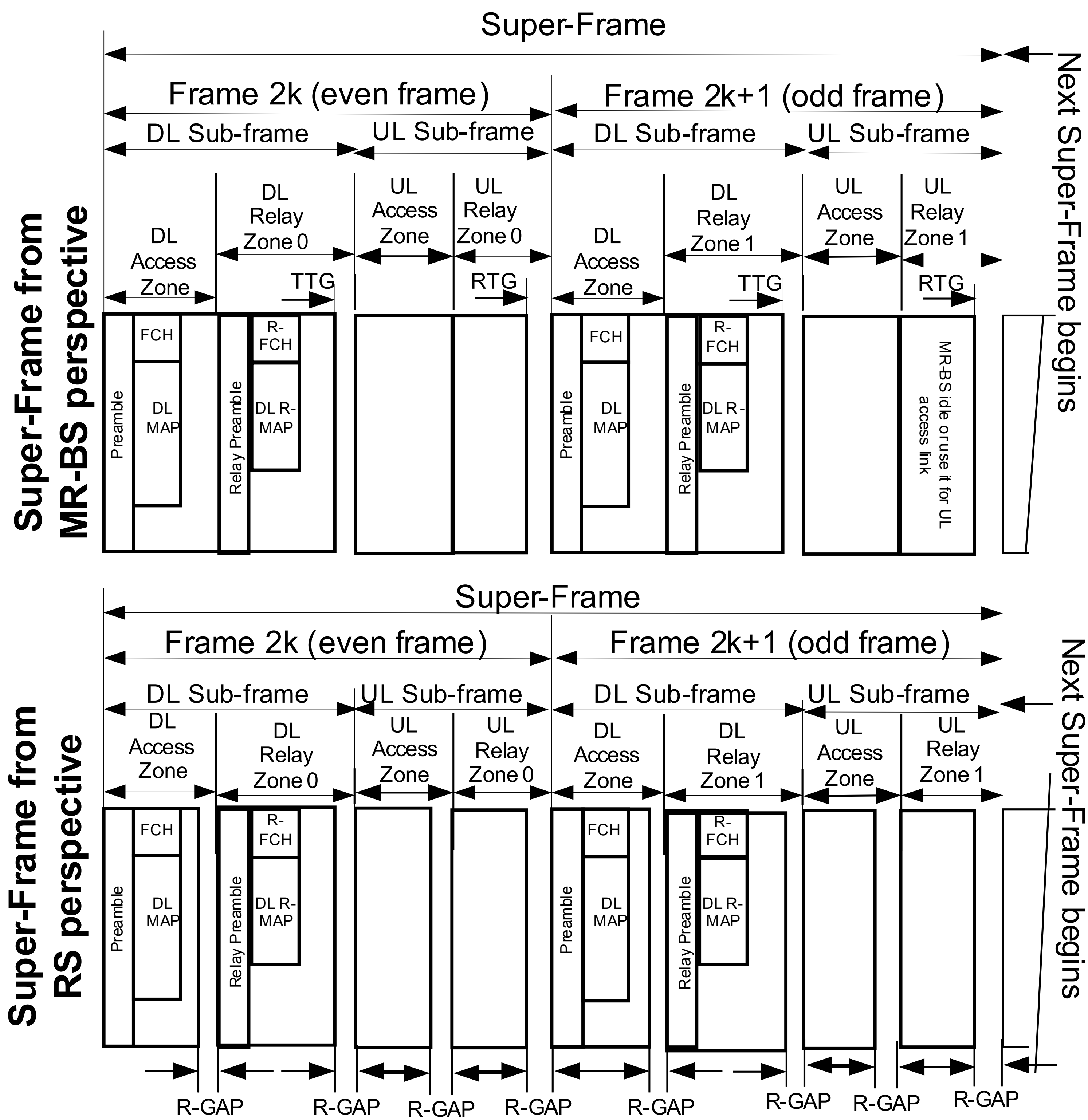
RSs which are an even number of hops away from the MR-BS are defined to be Even RSs while RSs that are an odd number of hops away from the MR-BS are defined to be Odd RSs. Even RSs could be assigned to transmit to their child Odd RSs in the DL Relay_Zone in frame 0 and receive from them in the UL Relay_Zone in frame 0. Odd RSs could be assigned to transmit to their child Even RSs in the DL Relay_Zone in frame 1 and receive from them in the UL Relay_Zone in frame 1. This odd-even structure allows RSs to receive from /transmit to their parent RSs in one set of Relay_Zones and to transmit to / receive from their child RSs in another set of Relay_Zones.

2.3 Reasons and trade-off for choosing M > 2

The two frame configuration in 2.1 is only one example of how our super-frame structure can be used and there are reasons why more than 2 frames within a super-frame structure are needed:

1. First is about traffic inbalance between odd and even frames. For example, if we have a three hop system, the first hop traffic would be higher than the second hop. Then, the total odd hop traffic (1st and 3rd hop) is much more than the even-hop traffic. We can balance this by having two odd hop frames and one even hop frames in the super frame.
2. If a MRS is to handoff from an odd-group parent to an even-group parent, having only 2 frames per super-frame will not work. This will require the MRS to receive and transmit at the same time.
3. Choosing larger M reduce the number of RSs transmitting in the same relay zone and therefore reduce interference. However, it may increase system latency.
4. To support multi-path from MR-BS to MS, M must be greater than 2.

Figure 2. k[th] super-frame structure for M=2



3 Proposed text changes

+++++++++++ start text proposal ++++++++++++++++++++++++++++++++++

[Insert the following after the end of section 3:]

Relay GAP: a gap placed between access and Relay_Zones or between two Relay_Zones which allows stations to switch from receive mode to transmit mode or from transmit mode to receive mode.

[Make the indicated modifications to section 4:]

~~**R-TTG:** Relay-TTG.~~
~~**R-RTG:** Relay-RTG.~~
R-FCH: Relay-FCH
R-MAP: Relay MAP.
R-GAP: Relay GAP

[Make the indicated modifications to section 8.4.4.7.2.1:]

8.4.4.7.2.1 MR-BS frame structure
For the TDD mode, an example of the MR-BS frame structure is shown in Figure xxx.

Each MR-BS frame begins with a preamble followed by an FCH and the DL MAP and possibly UL MAP. The DL sub-frame shall include at least one DL Access Zone and may include one or more DL Relay_Zones. The MR-BS shall be assigned to transmit or be idle in each of the DL Relay_Zones. The UL sub-frame shall include at least one UL Access Zones and it may include one or more UL Relay_Zones. The MR-BS shall be assigned to receive or be idle in each of the UL Relay_Zones. In each frame, the TTG shall be inserted between the DL sub-frame and the UL sub-frame. The RTG shall be inserted at the end of each frame. In the DL Access Zone, the subchannel allocation, the FCH transmission, and the FCH shall be defined as in Section 8.4.4.2.

The DL Relay_Zone may begin with a relay preamble and shall include an R-FCH and an R-MAP. The MR-BS may transmit a relay preamble and shall transmit R-FCH, and R-MAP in those DL Relay_Zones in which it is assigned to transmit. The structure of the relay preamble shall be the same as specified in section 8.4.6.1.1. The set of preamble modulation sequences transmitted in the relay preamble shall be different from the preamble modulation sequences transmitted in the Frame Start Preamble. In the DL Relay_Zone, the subchannel allocation may be the same as that in the DL Access Zone. The R-FCH may be the same as the FCH in the DL Access Zone. Other attributes of the MR-BS frame and the RS frame such as transition between modulation and coding, presence of multiple zones, may be the same as those described in 8.4.4.2.

The number, size, and location of the Relay_Zones shall be configurable.

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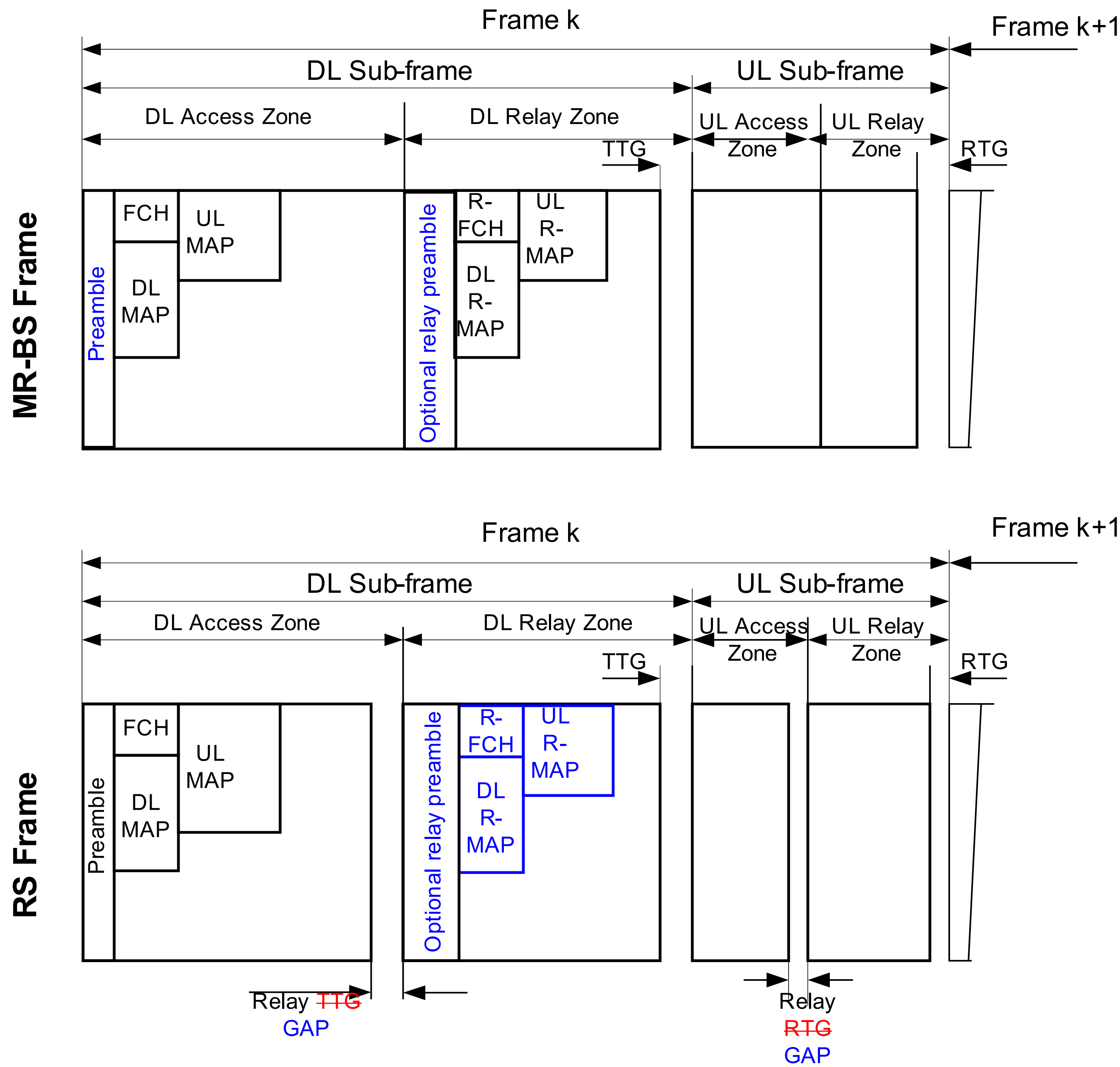

Figure xxx Example of minimum configuration for a multi-hop, in-band non-transparent relay frame structure

[Make the indicated modifications to section 8.4.4.7.2.2:]

8.4.4.7.2.2 Relay frame structure

For the TDD mode, an example of an RS frame structure is shown in Figure xxx.

The Relay Station transmits its frame start preamble time aligned with its serving MR-BS frame start preamble.

The DL sub-frame shall include at least one DL Access Zone and may include one or more DL Relay_Zones. Each RS shall be assigned to transmit, receive, or be idle in each of the DL Relay_Zones. An ~~R-TTG~~ R-GAP may be placed between a DL Access Zone and a DL Relay_Zone and between adjacent DL Relay_Zones.

The UL sub-frame may include one or more UL Access Zones and one or more UL Relay_Zones. Each RS shall be assigned to transmit, receive, or be idle in each of the UL Relay_Zones. An ~~R-RTG~~ R-GAP may be placed between a UL Access Zone and a UL Relay_Zone and between adjacent UL Relay_Zones.

~~If the relay station switches from transmission to reception mode, an R-TTG shall be required. If the relay station switches from reception to transmission mode, an R-RTG shall be required. There may be more than one R-TTG and more than one R-RTG inserted in the RS frame. In each frame, the TTG shall be inserted between the DL sub-frame and the UL sub-frame. The RTG shall be inserted at the end of each frame.~~
An R-GAP shall be inserted between the DL access zone the DL Relay_Zone. In addition, an R-GAP shall be inserted between the UL access zone and UL Relay_Zone. An R-GAP shall be inserted between 2 DL Relay_Zones and between 2 UL Relay_Zones. More, an R-GAP shall be inserted between the DL sub-frame and the UL sub-frame. An R-GAP shall be inserted at the end of each frame.

The contents of the FCH, DL-MAP, and UL-MAP in the Relay Frame may be different from those in the MR-BS Frame.

Each RS frame begins with a preamble followed by an FCH and the DL MAP and possibly a UL MAP. A DL Relay_Zone may begin with a relay preamble and shall include an R-FCH and an R-MAP. The structure of the relay preamble shall be the same as specified in section 8.4.6.1.1. The set of preamble modulation sequences transmitted in the relay preamble shall be different from the preamble modulation sequences transmitted in the Frame Start Preamble. In the DL Access Zone, the subchannel allocation, the FCH transmission, and the FCH shall be as defined in Section 8.4.4.2.

The number, size, and location of the Relay_Zones shall be configurable.

[Insert section 8.4.4.7.2.3 at the end of section 8.4.4.7.2.2:]

8.4.4.7.2.3 Super-frame structure to support multi-hop (>= 2 hops)

An example of an MR-BS and an RS super-frame is shown in figure xxxx. This super-frame structure collapse back to the frame structure proposed in 8.4.4.7.2.1 and 8.4.4.7.2.2 when M is set to 1. One or more MR-BS frames may be grouped into an MR-BS super-frame. The number of MR-BS frames that make up an MR-BS super-frame shall be configurable. One or more RS frames may be grouped into an RS super-frame. The number of RS frames that make up an RS super-frame shall be configurable. The number of MR-BS frames that make up an MR-BS super-frame shall be the same as the number of RS frames that make up an RS super-frame.

The DL Relay_Zones within the MR-BS frames that make up an MR-BS super-frame shall be uniquely identified within the super-frame. When super-frames are used, the MR-BS is assigned to either transmit or be idle in each of the DL Relay_Zones in the MR-BS super-frame.

The UL Relay_Zones within the RS frames that make up an RS super-frame shall be uniquely identified within the super-frame. When super-frames are used, an RS is assigned to either transmit, receive or be idle in each of the UL Relay_Zones in the RS super-frame.

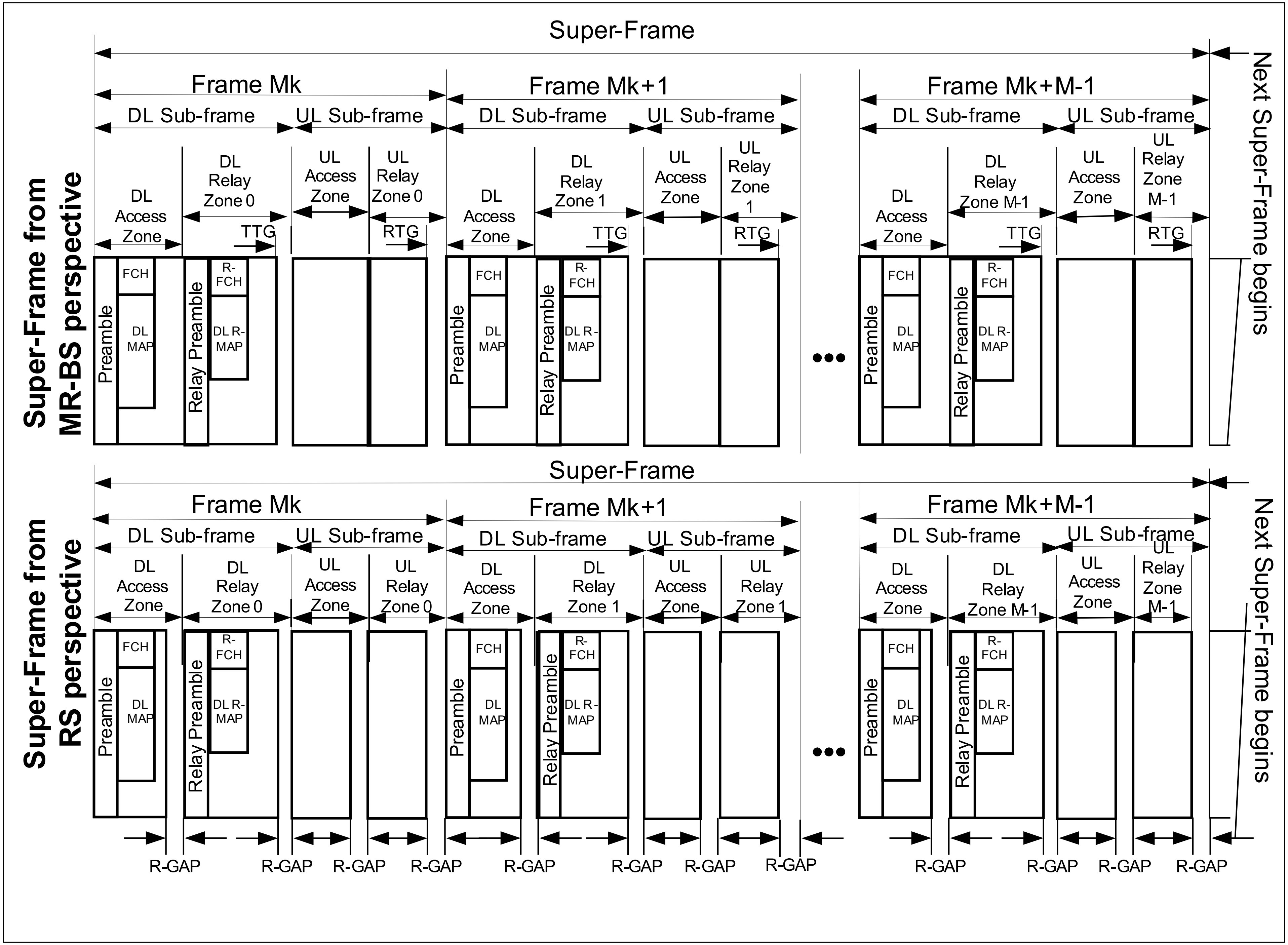
Super-Frame from MR-BS perspective
Super-Frame
Frame Mk
Frame Mk+1
Frame Mk+M-1
DL Sub-frame
UL Sub-frame
DL Access Zone
DL Relay Zone 0
UL Access Zone
UL Relay Zone 0
DL Relay Zone 1
UL Relay Zone 1
DL Relay Zone M-1
UL Relay Zone M-1
TTG
RTG
Preamble
FCH
DL MAP
Relay Preamble
R-FCH
DL R-MAP
Next Super-Frame begins
Super-Frame from RS perspective
R-GAP

Figure xxx Example of an M frame MR-BS and RS k^{th} Super-Frames

+++++++++++++++++++++ *End of text proposal* +++++++++++++++++++++++