Project	**IEEE 802.16j Mobile Multihop Relay Task Group**
Title	**An adaptive frame structure for OFDMA-based mobile multi-hop relay networks**
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Re:	*Response to the call for technical proposal regarding IEEE Project 802.16j (i.e., IEEE 802.16j-06/034, "Call for Technical Proposals regarding IEEE Project P802.16j", December 12, 2006).*
Abstract	*An adaptable frame structure design for 802.16j is described*
Purpose	*To adopt the frame structure proposed herein into IEEE 802.16j.*
Notice	
Release	
Patent Policy and Procedures	

Adaptive Frame Structure for OFDMA-based Mobile Multi-hop Relay Networks

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1. Introduction

Current OFDMA-based cellular wireless network (e.g., IEEE 802.16) invariably confines its operation to a point-to-multipoint topology, wherein two and only two types of network entity, namely base station (BS) and mobile station (MS), can exist. As illustrated in **Figure 1**, a centralized control entity (i.e., BS) has the sole authority to manage and coordinate the communications initiated by or terminated at the end users (i.e., MS) that are in the direct transmission range of the BS. Regardless of whether the communication is between two MSs that are directly associated with the BS, or is between an MS and an external network entity, all the traffic have to pass through the BS.

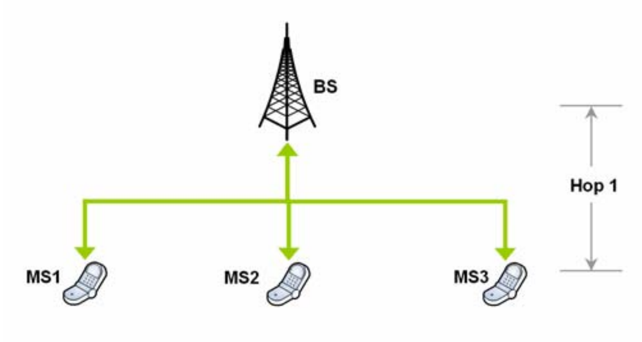

Figure 1: Topology for OFDMA-based point-to-multipoint (PMP) wireless networks.

Accordingly, the OFDMA frame structure in the current wireless system (e.g., IEEE 802.16-2005), which governs the basic channel access of BS and MS in both the time and frequency domain, has been designed specifically to support the PMP operation.

Due to significant loss of signal strength along the propagation path for certain spectrum, the coverage area of broadband wireless service offered on that band is often of limited geographical size. In addition, blocking and random fading frequently result in areas of poor reception or even dead spot within the coverage region. Conventionally, this problem has been addressed by deploying BSs in a denser manner. However, the high cost of BSs and potential aggravation of interference, among others, render this approach less desirable. As an alternative, a relay-based approach can be pursued, wherein low cost relay stations (RS) are introduced into the network to help extend the range, improve service, and eliminate dead spots, all in a cost-effective fashion.

However, the state-of-art frame structure, which was initially designed only for a single hop point-to-multipoint (PMP) OFDMA-based network, is inadequate to support the function of relay stations in the wireless network. To address this issue, new frame structure has to be initiated to facilitate relaying function, and ultimately materialize the potential benefit.

2. Summary of Proposal

To maintain backward compatibility and interoperability with the legacy MSs that are in the direct transmission range of BS and/or RSs, a two dimensional format similar to the frame structure in 802.16e has been designed.

The frame structure proposed here has the flexibility to address the degree of frequency reuse and provide the system with the choice of adjusting latency and bandwidth according to the users' requirements.

There are three options:

Option A: Single access zone and multi relay zones within a single sub-frame where the frame is also the super frame
Option B: Single access zone and single relay zones within each sub-frame
Option C: Single access zone and two or more relay zones within each sub-frame and two or more frames in a super frame

Option A, as shown in Figure 2, provides smaller delay and is useful for services that require low latency. Option A is where the super frame is the frame. In other words, the frame is also the super frame. The disadvantage of this option is the time gap between the relay zone could be large because it has to accommodate the processing time for decoding and encoding of the relaying data and therefore some bandwidth is compromised.

Option B, as shown in Figure 3 and Figure 4, provides larger bandwidth and is useful for services that require higher data rate but are more tolerant to higher latency. The higher bandwidth is because of the null switching time that are required between the relay zones as in option A or C.

Option C is the combination of Option A and B that provides the compromise of higher bandwidth efficiency and lower latency compared to options A and B, respectively. Option C there is more than one relay zones in each sub-frame and more than one frame in each super frame.

Super frame is defined as the number of frames within which the information can be delivered from the MR-BS to the mobile associated with the access RS that is the furthermost from the MR-BS.

Therefore Option A has a super frame equals to ***one*** frame duration. The super frame length of option B depends on the number of relay hops. The super frame length of option C depends on the number of relay hops and number of relay zones within each sub frame.

Option A incurs a one-frame delay whereas the delay in option B depends on the number of hops and the degree of interference. There are potentially two variants of Option B, depending on the degree of the scheduler intelligence and the RF interference impact on frequency reuse. Variant 1 is simple and that is the MR-BS can only transmit on frame 0 (first frame) of the super frame. Variant 2 can be explained as followed. As shown in Figures 2, 3 and 4, the MR-BS can transmit on every even frame if:

1. sub-channel can be reused because there is negligible impact of its RF interference on Relay 3 reception and similarly of Relay 2's interference on Relay 1 reception. The RF interference level could be collected by the MR-BSs and the Relays and taken into account by the central or distributed scheduler or
2. the sub-channels are organized by the scheduler such that no two same sub-channels are used within a super frame or
3. the combination of items 1 and 2 to enable some sub-channels to be reused if RF interference is tolerable.

The design of the scheduler is not within the scope of this discussion.

Last but not the least, it is crucial for the MS associated directly with BS or with various RSs to perceive a frame structure that strictly conforms to the legacy format, for the sake of backward compatibility and interoperability.

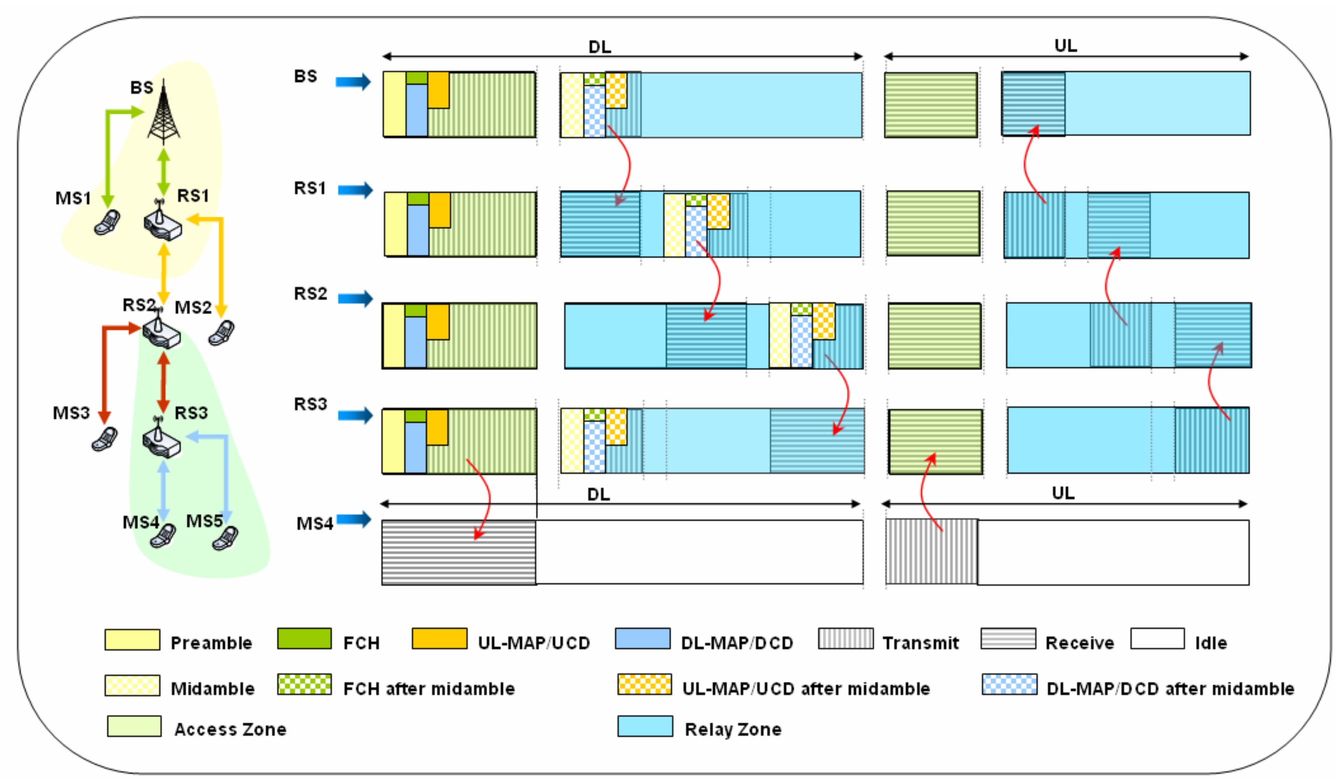

Figure 2: Option A ─ Frame structure with more than one relay zone in the DL and UL sub-frames

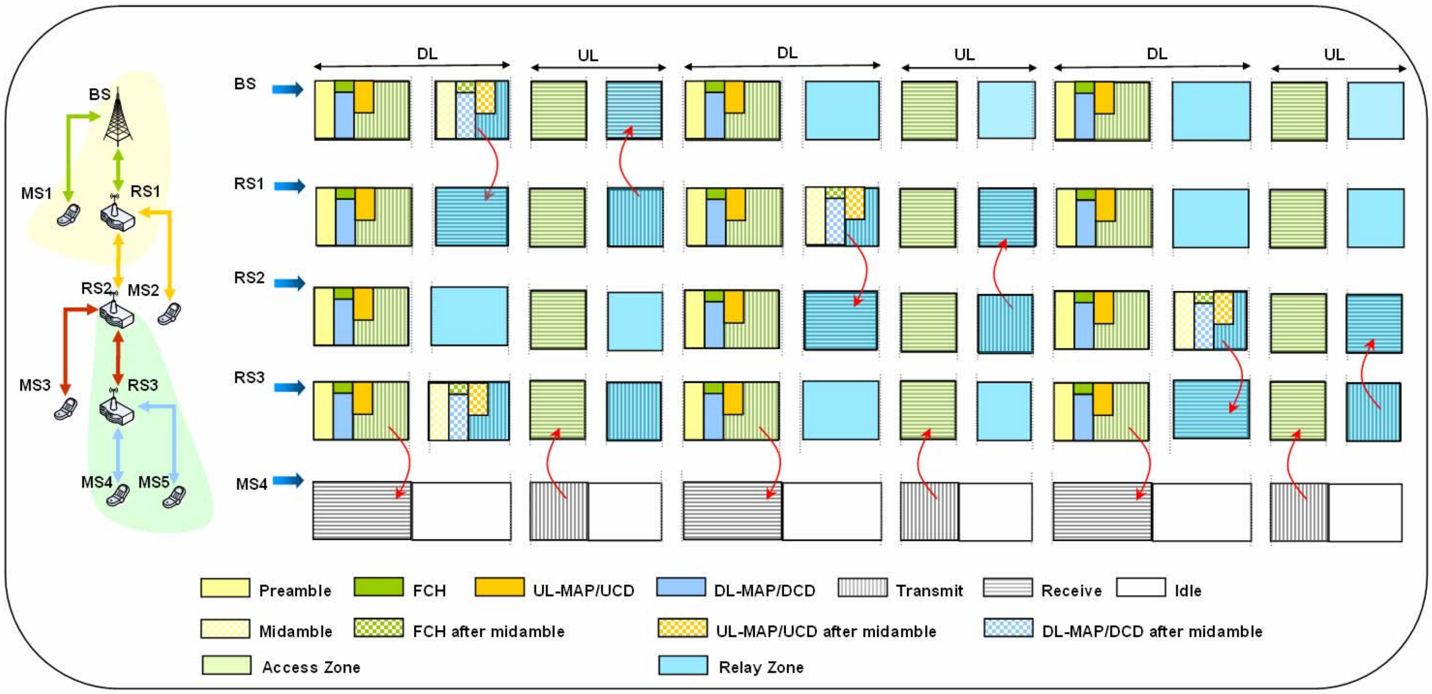

Figure 3: Option B variant 1 — A super frame with single relay zone in each DL and UL sub-frame – one transmission in each super frame

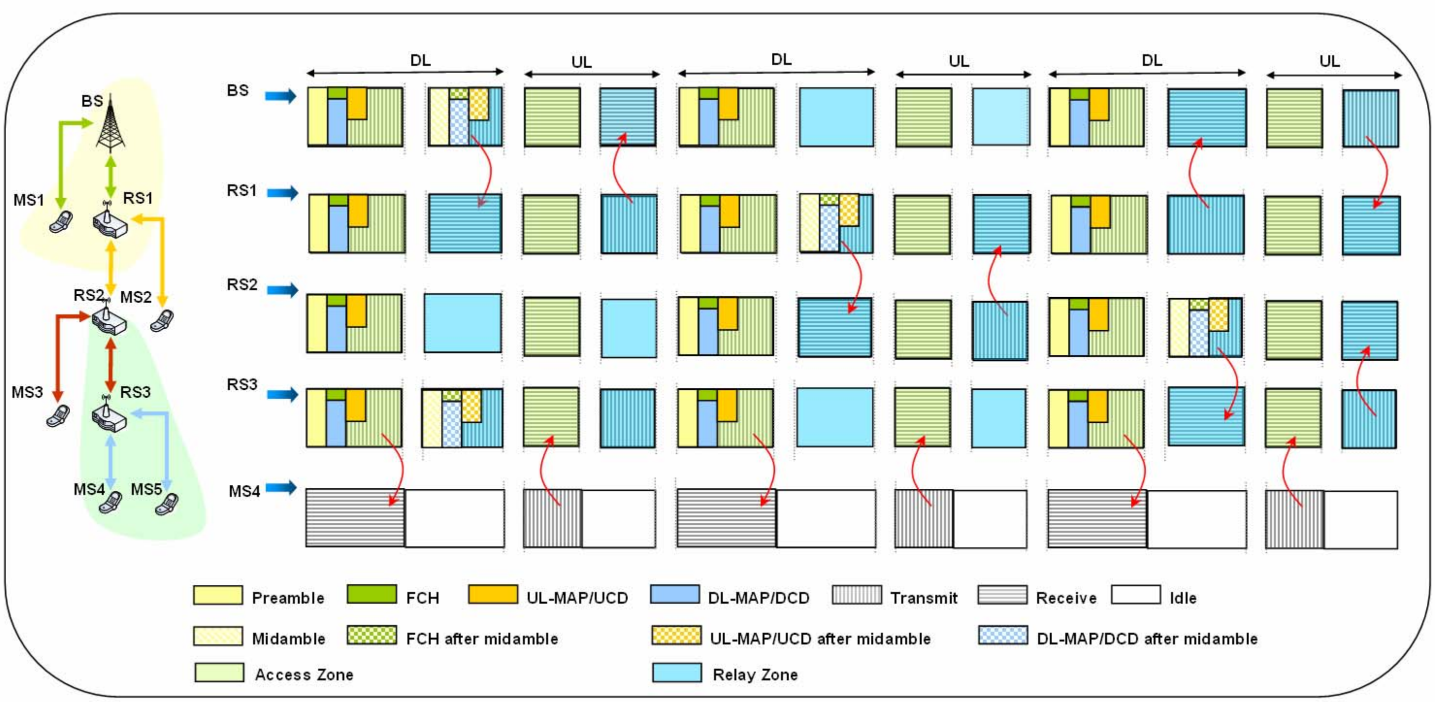

Figure 4: Option B variant 2 — A super frame with single relay zone in each DL and UL sub-frame – multiple transmissions in each super frame where interference impact is negligible

3. Proposed Text Changes

8. PHY

[Insert new subclause 8.4.4.8]

8.4.4.8 MR-BS frame structure

The frame structure shown in Figures 2, 3, 4, 5 and 6 are for a TDD mode of operation. As shown in Figure 5, every DL sub-frame starts with the structure similar to 802.16e standards, that is, a preamble, an FCH, DL and UL MAPs for the access and they are backward compatible to the MS. This defines the DL access zone within the DL sub-frame. This access zone is followed by the relay TTG (R-TTG) or relay RTG (R-RTG) and to be followed by one or more DL relay zone. There is a R-TTG or R-RTG between each pair of DL relay zones if there are more than one DL relay zone. The relay zone may be assigned by the scheduler to transmit, receive or stay idle. If it transmits, it will also consist of a preamble, known here as the mid-amble. The mid-amble is followed by relay FCH (R-FCH) and relay DL MAP (R-DL MAP) and relay UL MAP (R-UL MAP) and they are transmitted on those relay zones that are assigned to transmit.

Similarly, for the UL sub-frame, it starts with the UL access zone, similar to 802.16e standards and is backward compatible to the MS. This defines the UL access zone within the UL sub-frame. This UL access zone is followed again by a R-RTG or R-TTG and one or more UL relay zone. Similar to the DL sub-frame, there is a R-RTG or R-TTG between each pair of UL relay zones if there are more than one UL relay zones. The UL relay zone may be assigned by the scheduler to transmit, receive or stay idle.

As depicted in Figure 5, the frame structure is for in-band relay operation. The number of relay zone in the DL sub-frame "n", may or may not be equal to the number of relay zone in the UL sub-frame "m". Both "n" and "m" can be equal to 1 which implies that there is only one relay zone in the sub-frames. When "n" and "m" equals to zero, it implies that the frame structure becomes the frame structure of the 802.16e standards. The duration of both the access and relay are flexible as long as they are confined within the duration of the sub-frame.

Similar to the 802.16e standards frame structure, a time gap TTG is inserted between a DL and an UL sub-frames and a time gap RTG is inserted between two frames.

In the DL and UL access zones, all the functionalities and frame structures are similar to the 802.16e and defined in section 8.4.4.2.

The frame structure of Figures 5 and 6 are meant to support a multi-hop relay network. It is flexible to support for two or more hops, whether the hops are in a chain or a tree like structure. It is also flexible to address services where short latency is critical and those which are not.

The number of DL relay zones per sub-frame will be determined by the scheduler and the latency and bandwidth requirements. Similarly the allocations of the sub-channels will also be determined by the scheduler to maximize frequency reuse and minimize RF interference.

Figure 6 depicted a frame structure for out-of-band relaying network. In this case, we are assuming there are two radios within a relay unit, operating at different frequencies. The frame structure is almost the same as those for the in-band relaying network except for the Access Zone. If the carrier frequency of the relaying is closed to that of the in-band carrier, that is, Option A, isolation between the two radios would becomes a challenge. Under these circumstances, the access zone (or idle zone) of the out-of-band has to be in synchronization and time aligned with the in-band access zone. In other words, both radio cannot transmit and receive at the sametime. The same applies for the rest of the relay zones. If the carrier freuquency of the relaying is very far from that of the in-band carrier, then simple filtering would be able to isolate the two radios. Under these circumstances, the former access zone can be used also as the relay zone as depicted in Figure 6, Option B. . In this case, the first relay zone (zone 0) mid-amble becomes the preamble. Under this circumstances, one radio could be solely used for access and the other for relaying.

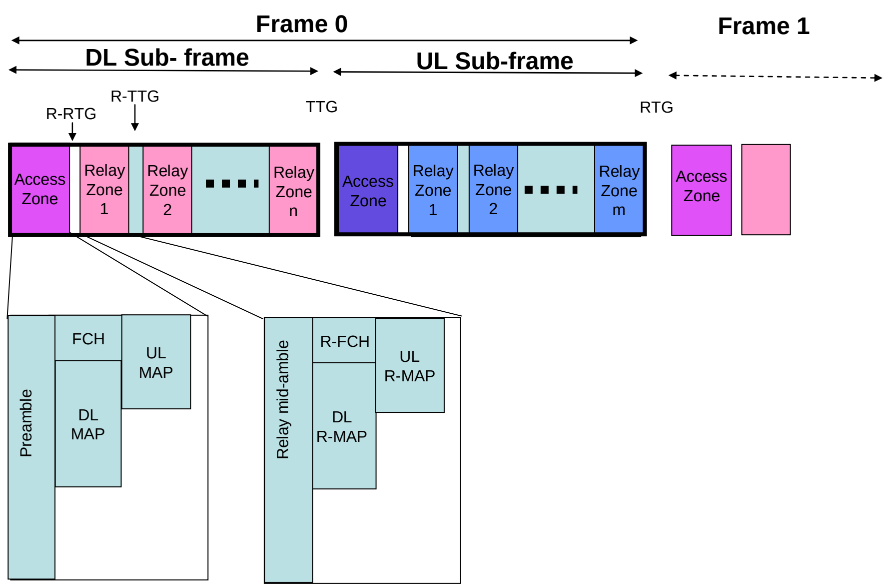

Figure 5: Frame structure for in-band relay network

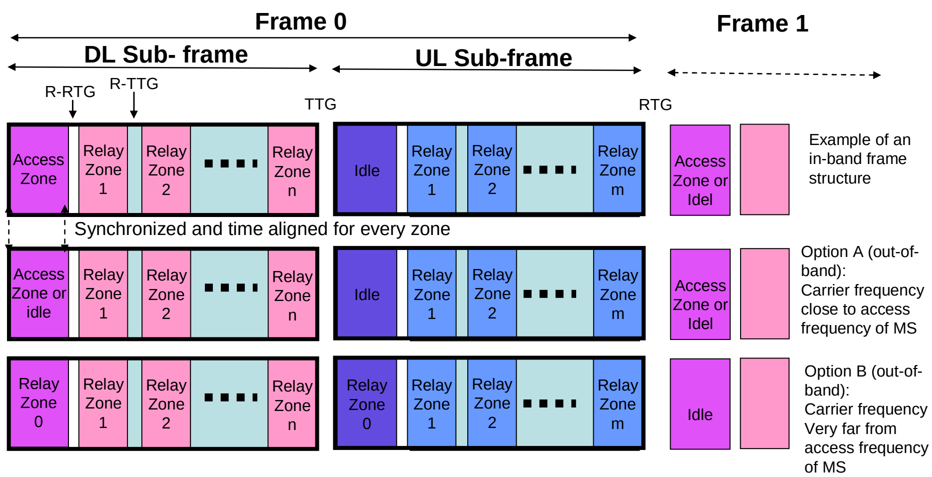

Figure 6: Frame structure for out-of-band relay network

4. References

[1] "IEEE Standard for Local and Metropolitan Area Networks − Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands," IEEE Computer Society and the IEEE Microwave Theory and Techniques Society, February 2006.