Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**A Frame Structure Design for OFDMA-based Multihop Relay Networks**
Date Submitted	**2006-11-14**
Source(s)	Jeffrey Z. Tao, Koon Hoo Teo, Jinyun Zhang] Mitshubishi Eletric Research Lab 201, Broadway, Cambridge, MA 02139, USA — Voice: 617 621 (7557, 7527, 7595) Fax: 617 621 7550 Voice: Email: Tao, Teo, Jzhang]@merl.com Toshiyuki Kuze Mitshubishi Eletric Corp 5-1-1 Ofuna Kamakura, Kanagawa 2478501, Japan — Voice: +81-467-41-2885 Fax: +81-467-41-2486 Email] kuze.toshiyuki@ah.MitsubishiElectric.co.jp
Re:	IEEE C802.16j-06/226
Abstract	An in-band adaptable frame structure design for 802.16j is described.
Purpose	Adopt the frame structure suggested herein into IEEE 802.16j.
Notice	
Release	
Patent Policy and Procedures	

A Frame Structure Design for OFDMA-based Multihop Relay Networks

Jeffrey Tao, Koon Hoo Teo, Jinyun Zhang
Mitsubishi Electric Research Lab
201 Broadway
Cambridge, MA 02139 USA

Toshiyuuki Kuze
Mitsubishi Electric Corp
5-1-1 Ofuna Kamakura, Kanagawa, 2478501, Japan

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.

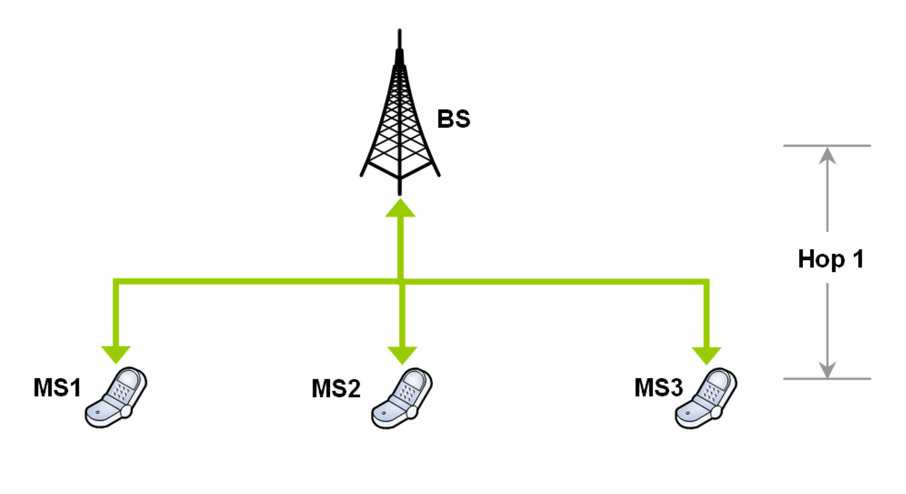

Figure 1: Topology for OFDMA-based point-to-multipoint (PMP) wireless networks.

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.

For instance, **Figure 2** depicts the frame structure for OFDMA-based time-division multiplexing (TDD) 802.16 PMP network. The frame structure spans both the time and frequency domain, which are represented by horizontal and vertical axes, respectively. Logically, the frequency band is divided into *N* segments, each of which is then assigned to a separate cell, thereby achieving a frequency reuse factor of *N*. Between two consecutive frames, an idle period called *Receive to Transmit Gap* (RTG) has to be waited, so that the BS can have sufficient time to switch its radio from *receiving* to *transmission* mode.

The frame structure for each segment is further exemplified in the lower part of **Figure 2**. Each frame consists of a downlink (DL) subframe, wherein the BS transmits to the MSs in the cell; and an uplink (UL) subframe, wherein multiple MSs access the channel. The DL subframe starts with a preamble, which spans the entire frequency band allocated to that corresponding segment, and lasts for a symbol time. Upon the successful reception of preamble, MSs can synchronize with the BS, and estimate the condition of the channel between them and the BS. Given the criticality of the preamble, it is always transmitted at the most robust rate to assure proper reception at all the MSs in the coverage area. In the symbol that immediately follows the preamble, BS transmit a *frame control header* (FCH) and a *downlink MAP* (DL-MAP) message to notify MSs of the resources and schedule allocated for ensuing DL data transmission within the current frame. The uplink transmission schedule is contained in the uplink MAP (UL-MAP) message, which is transmitted after the DL-MAP message.

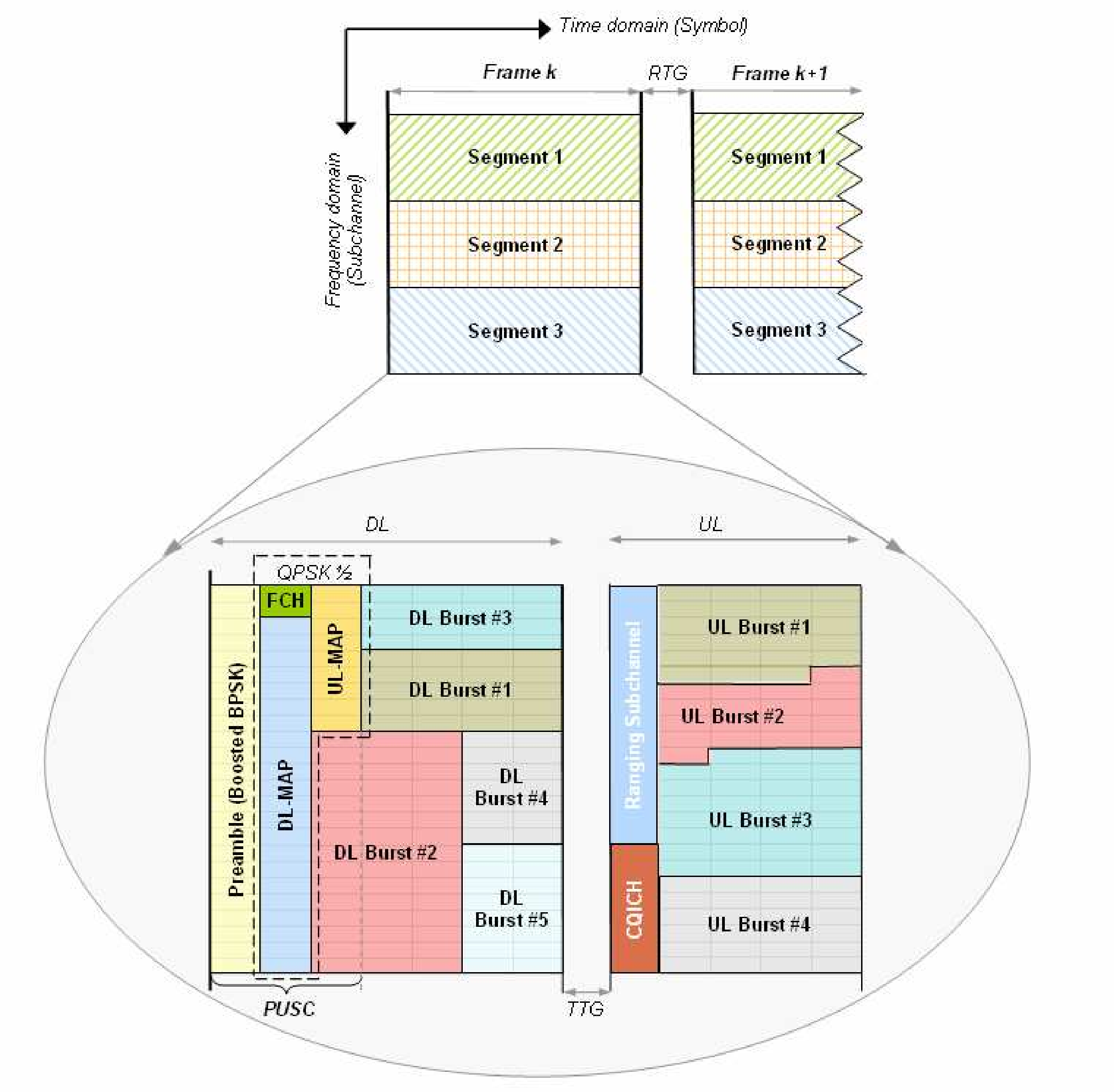

Figure 2: Frame structure for OFDMA-based IEEE 802.16 point-to-multipoint (PMP) operation.

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 invented to facilitate relaying function, and ultimately materialize the potential benefit.

2. The relay multiple hop network

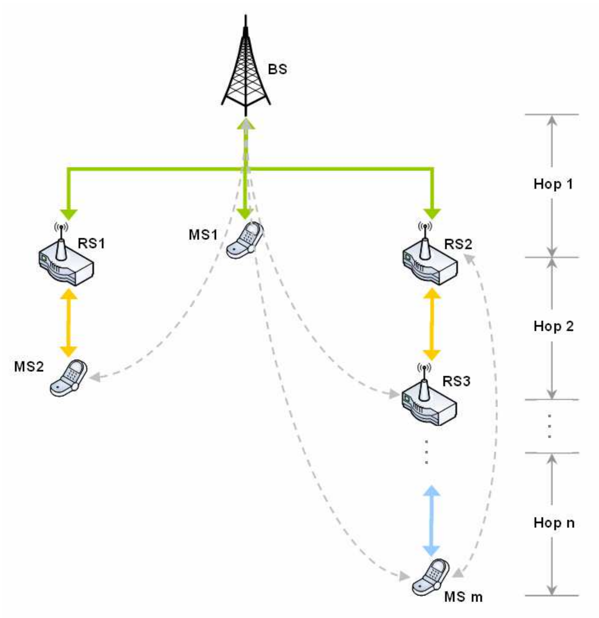

Figure 3: Topology *I* for OFDMA-based multihop relay wireless network.

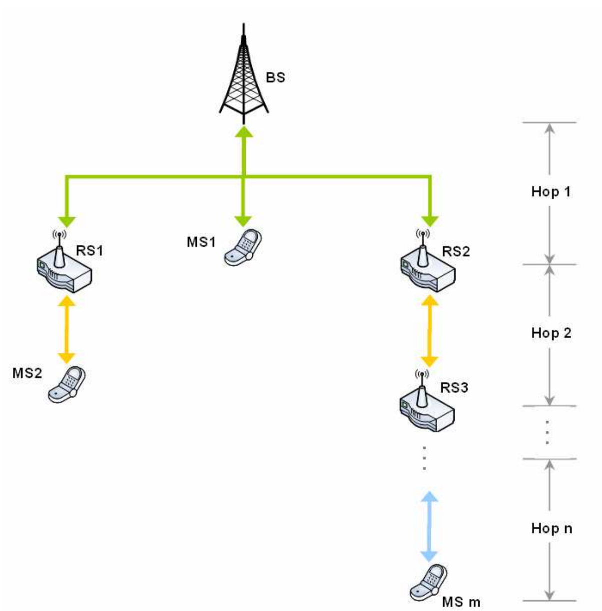

Figure 4: Topology *II* OFDMA-based multihop relay wireless network.

The wireless network where relays will be deployed can be divided into two distinct categories, as illustrated in **Figure 3** and **Figure 4**, respectively. In both figures, the solid arrowed lines are used to connect the network entities that are one hop away from each other, and thus can directly communicate with each other. Meanwhile, dotted arrowed lines represent the possible communication between two network entities that logically have multiple hops in between.

The key difference between the two network topologies is that RSs and MSs in **Figure 3** are probably able to receive from and transmit to the network entities which are more than one hop away from them directly, provided that proper modulation and coding schemes are selected. In **Figure 4**, however, radio signal propagation can only reach the stations that are one hop away from the transmitter.

For example, MS3 in **Figure 3** can be engaged in direct transmission with not only BS, but also RS2 and RS3. Meanwhile, MS3 can only establish a direct communication with RS3 in **Figure 4**.

3. The frame structure

Despite the difference described above, these two network topologies can share the same general framework for the frame structure design. 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 shown in **Figure 2** has been designed. **Figure 5** provides an example for an OFDMA-based multihop relay network, and the corresponding frame structure on each hop. For instance, MS2 should consider RS1 as its BS, while it is subject to the actual system design and implementation as to whether RS1 really performs all the functions of a BS, or just simply forwards traffic on behalf of the BS and thus is transparent to the MSs.

As indicated therein, the notion of downlink subframe and uplink subframe at BS and RS become more relaxed, as the logical downlink and uplink subframe may in fact contain uplink or downlink transmission, respectively.

In addition, provided that no other ongoing communication will be disrupted, the blank area or a subset of that within the frame structure of BS and RSs can also be allocated for communication, thereby achieving higher efficiency for resource utilization. For instance, RS 1 can transmit to BS during their respective zone y and x, while RS 2 is sending downlink packets to RS 3. The frame structure and related management messages should be properly extended to provide this flexibility, while the actual resource allocation should be determined by separate scheduling algorithms.

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.

A key notion of "zone" has been introduced in IEEE 802.16, which essentially refers to a set of contiguous OFDMA symbols in either downlink or uplink subframe that observe the same permutation formula. Possible permutation formulae that have already been defined in IEEE 802.16-2005 include partial usage of subchannel (PUSC), full usage of subchannel (FUSC), etc. It is important to note that all the subcarriers in the same OFDMA symbol must honor the same permutation method, and therefore belong to the same zone. A downlink or uplink subframe may contain multiple zones. However, no DL-MAP or UL-MAP allocation can span over multiple zones.

To define and characterize the frame structure for OFDMA-based multihop wireless network, it is apparently more appropriate to use the extended notion of “zone”, which now can also refer to a set of contiguous symbols assigned to the downlink RSs for uplink or downlink communication.

For any transmission that occurs on the kth hop ($k > 1$), logical zones can be allocated to the corresponding RSs and/or MSs for that purpose. The BS may or may not be aware of the detailed resource allocation inside the zone, depending on whether a centralized or distributed scheduling is adopted.

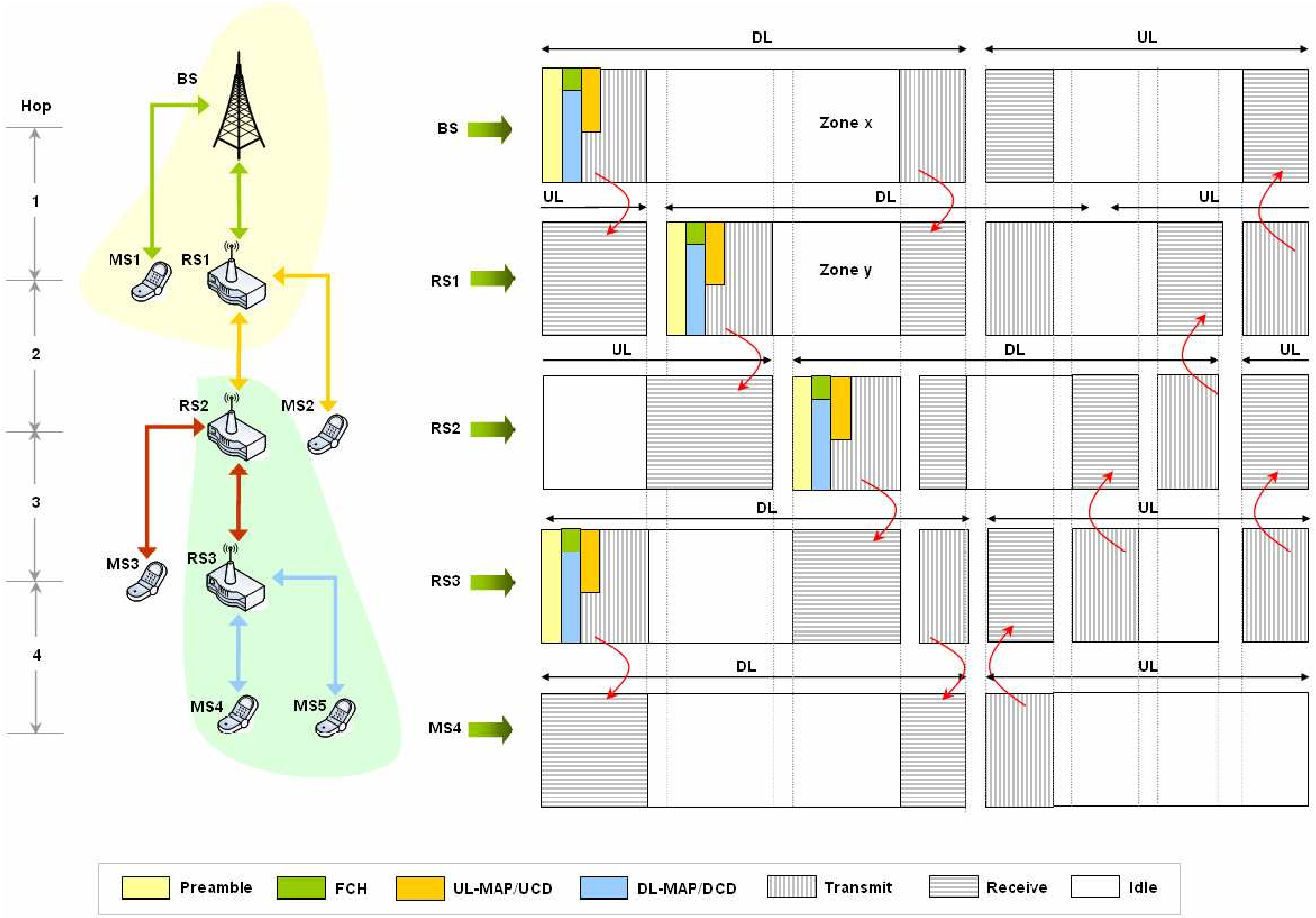

Figure 5: An example of multihop network, and the corresponding frame structure on each hop.

	Function	Extension/Enhancement Involved
DL	Switch to RX	Extend DL_zone_switch_IE, based on extended-2 IE format.
	Switch back from RX	Extend DL_zone_switch_IE, based on extended-2 IE format.
	Detailed schedule within RX interval/zone during logical DL subframe	Introduce DL_RX_MAP_IE, based upon the content of UL_MAP_IE and extended-2 IE format.
	Channel description	Extend TLVs in DCD to describe UL channel.
UL	Switch to TX	Extend UL_zone_switch_IE, based on extended-2 IE format.
	Switch back from RX	Extend UL_zone_switch_IE, based on extended-2 IE format.
	Detailed schedule within TX interval/zone during logical UL subframe	Introduce UL_TX_MAP_IE, based upon the content of DL_MAP_IE content and extended-2 IE.
	Channel description	Extend TLVs in UCD to describe DL channel.

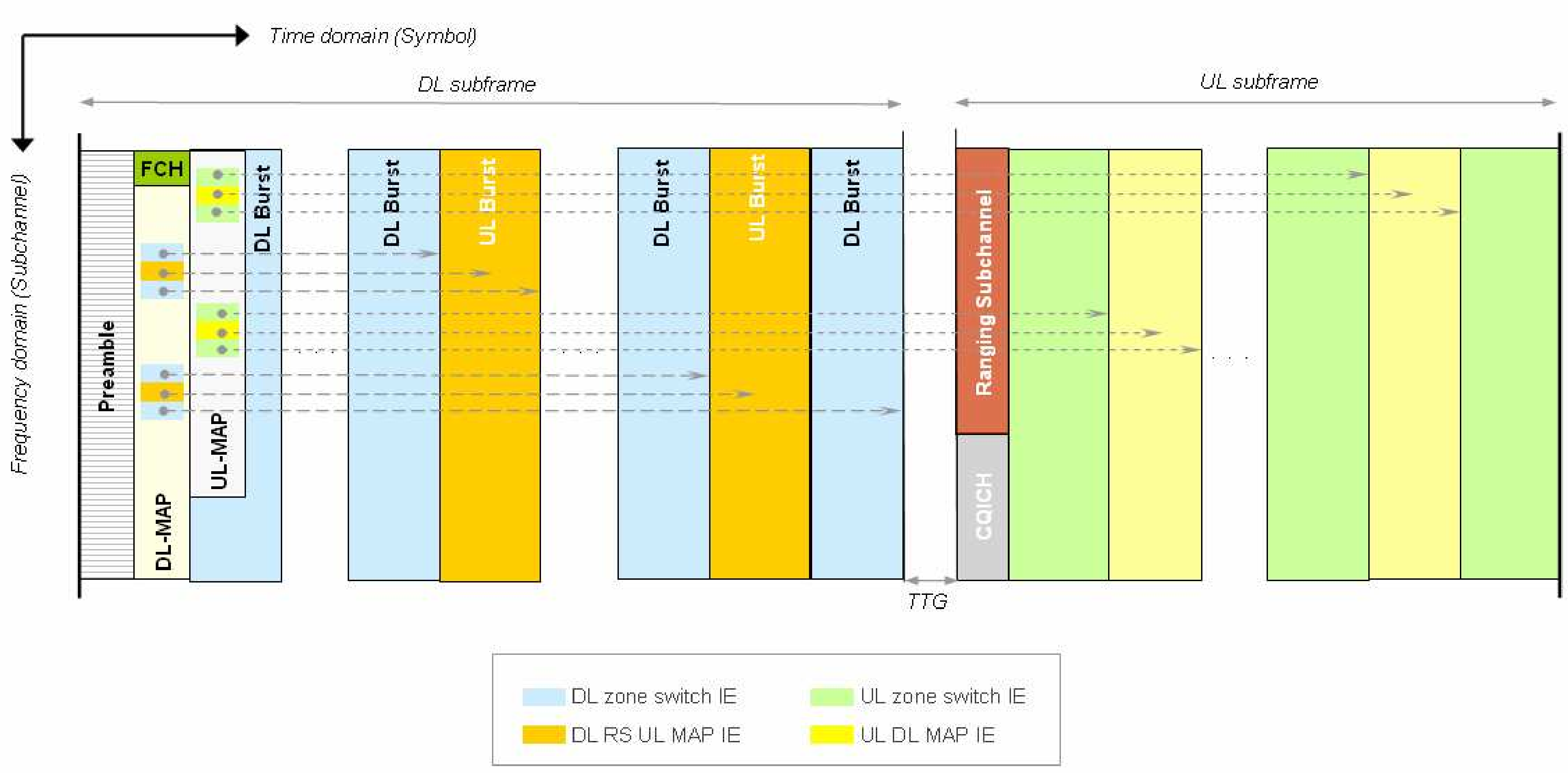

Figure 6: Frame structure design for OFDMA-based IEEE 802.16 multihop relay network.

Figure 6 depicts a frame structure for the OFDMA-based multihop relay wireless network. To ensure that the legacy MSs associated with the BS and/or RSs can still function, it is imperative to start the frame structure with preamble and related management messages (i.e., FCH, DL-MAP, DCD, UL-MAP and UCD), which should assume such a format and occupy such a frequency/symbol position that it can be understood by the legacy MSs.

On the other hand, extension of the current message and introduction of new information elements (i.e., related to zone switch and MAP) have to be made in order to support the operation of relay stations, given that the proceeding constraints can be met.

4. Conclusion

This design described an adaptive frame structure for a multiple hop TDD OFDMA network.

In summary,

a. The frame structure has a logical downlink and uplink subframe structure which is further partitioned into intervals/zones – time division

b. The starting and end time of these intervals zones can be indicated by extended DL Zone_Swtich_IE and UL_Zone_Switch_IE

c. To avoid potential interference, BS and RSs may need to announce idle or null periods in logical DL and UL subframes

d. Allow simultaneous transmission of RS and BS or RS and RS depending on the scheduler – frequency reuse

e. The frame structure supports both centralized and distributed schedulers

f. The minor revisions/extensions of the zone concept enable the frame structure the flexibility to support wide variety of communication needs and network topology/scenario