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Source(s)	Mariana Goldhamer Alvarion ltd. 21A, Ha Barzel Street Tel Aviv E-mail: mariana.goldhamer@alvarion.com
Re:	[16jm] Relay Frame Structure - call for proposals
Abstract	
Purpose	Actions: 1. Modification of ToC 2. Capture of the text in the SDD
Notice	
Release	
Patent Policy	

802.16m Frame structure for TDD Multi-Hop Relays in OFDMA domain

Mariana Goldhamer
Alvarion Ltd.

Introduction

The approach within the draft P802.16j/D3 includes two time intervals dedicated to Relay operation per MAC Frame. However, due to the limitation of the small number of available sub-frames in 802.16m SDD, this approach has serious performance limitations. Additionally, it is highly desired the usage of the MIMO technology in the RS-BS or RS-RS communication. Because the number of possible sub-frames and hence Zones in a MAC Frame is highly limited, in a practical system implementation is almost impossible to use MIMO within a Relay allocation.
This contribution provides an OFDMA-domain solution to overcome this problem. The solution is enhanced with better spectral efficiency based on the definition of dedicated and shared allocations for access mode (BS/RS to SS) operation.

Scarcity of sub-frames

Limitations occur due to the usage of time separation and the short MAC Frame duration. The limitation, system wise, is generated by having too many features to be supported in the time domain. Many of these features did not exist at the time when 802.16e was drafted. See below a list of features to be supported by an 802.16e system evolved to 16m, noting that time domain separation is the only accepted solution by now for:

- Permutations and Reuse factor:
  - PUSC (Reuse 3)
  - AMC permutation
  - PUSC with all subchannels (Reuse 1)
- Multicast/Broadcast Zone
- DL Sub-channelization Zone
- MIMO Zone
  - AMC permutation
  - Diversity permutation
  - Diversity MAP or non-diversity MAP
  - Matrix A
  - Matrix B
  - Matrix C
  - 2 or 3 antennae
- Relays (new)
- Legacy support (new)
- Coexistence with Bluetooth (new)
- Coexistence with 802.11 (new)
- Coexistence with UMTS/LTE (new).

The solution to this problem is to transfer part of the time-separated activities in OFDMA domain.

With respect to the relay operation, which consists of 4 different time intervals in one Frame, the partition of the sub-frames with the 802.16m SDD concepts becomes straightforward:

- 3 sub-frames for BS DL (3*3= 9slots), access mode; includes the forward Relay Station (RS) feeding
- 2 sub-frames for RS-DL (2*3=9slots), access mode
- 2 sub-frames for BS-UL (2*2=4 slots), access mode, includes the Relay backward traffic
- 1 sub-frame for RS-UL, access mode (2 slots, which is not enough, but this is what is left).

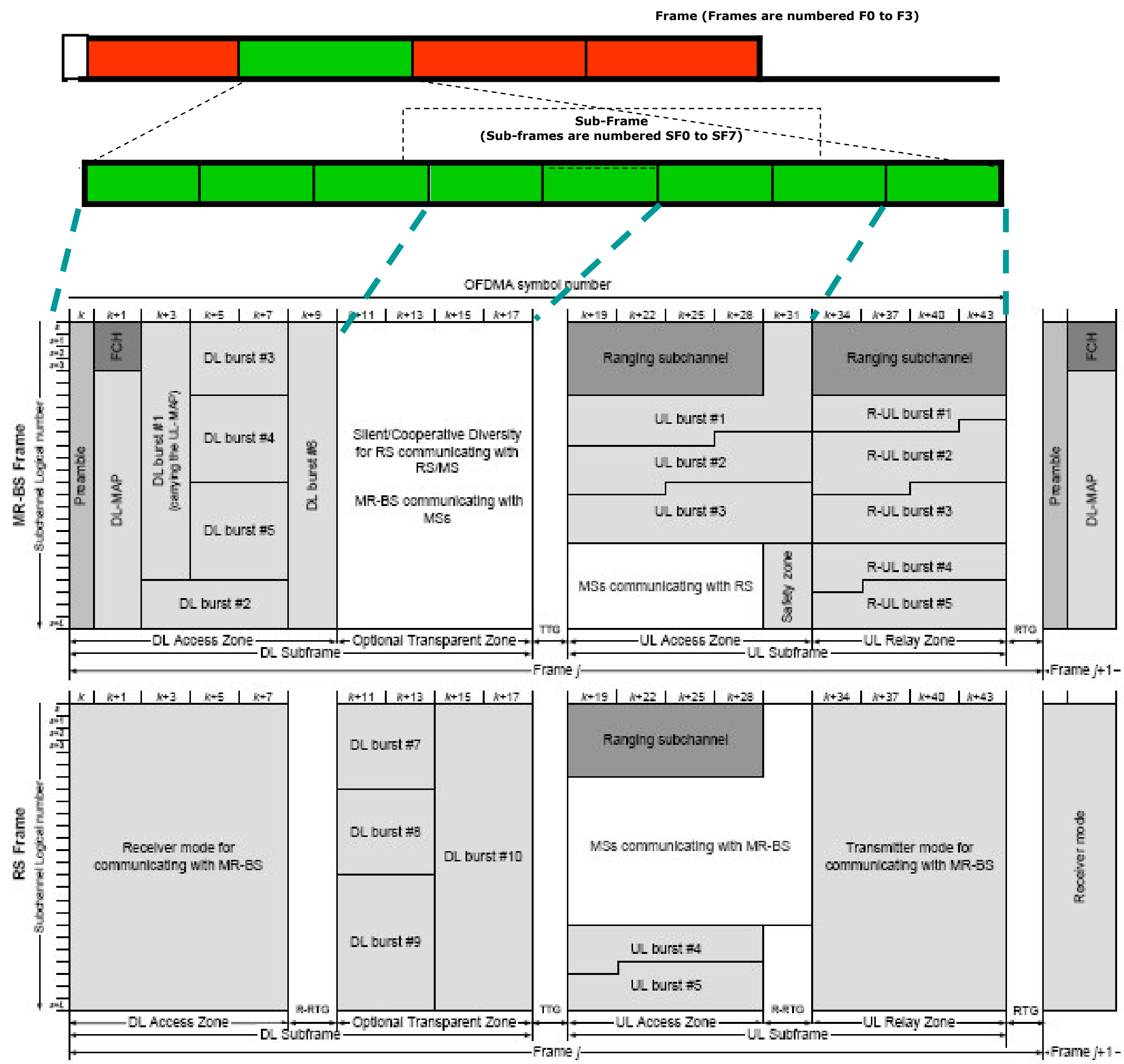

Figure 270a—Example of configuration for an in-band transparent relay frame structure[1]

Fig. 1 Applying the sub-frame concept to Relays

However, such a partition conducts to poor spectral efficiency, especially in up-link, where the MAC and fragmentation headers of every UL (uplink) transmission take a considerable part of the 4 available slots in the BS UL operation. For the Relay operation is even worse, because there are and only two available UL slots. Additionally, due to the excessive segmentations, there are important overheads in both DL (downlink) and UL control messages (MAPs).

The addition of MIMO (multiple-input-multiple-output) Zones, suitable for BS-RS communication, is impossible due to the small number of sub-frames (available symbols).

Legacy support

The Legacy support (802.16j) can be always done by using an appropriate number of DL and UL sub-frames allocated for the 802.16j “Relay Zone”. The TDD Proposal 2 needs only the insertion of a “Legacy” sub-frame for UL 802.16j operation. The DL operation in the Proposal 2 is similar with the DL operation of the 802.16j relays.
No “legacy” support is needed for the FDD operation.

Interference map

In the general case a Relay Station (RS) will have a number of RS surrounding it, which for the highest range and data traffic should be separated in frequency domain. For example, we will consider that the Relays have sector antennas in the access mode; in this configuration the interference created to one SS located at the cell edge is shown in the following figure:

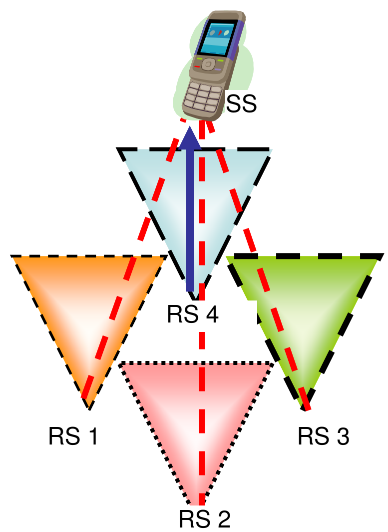

Fig. 2 The strongest interferers of a sector RS

With omni antennas there are also 4 interfering cells.

In order to separate the 4 cells which are interfering are needed 4 segments (sub-channel groups) in the OFDMA domain. These segments will allow for the maximum cell size and will be used essentially for increasing the SINR (signal to interference and noise ratio) of specific users, typically at the cell margin. A better spectral efficiency will be obtained if the links not interfering one which each other will be grouped in a “shared” allocation built from sub-channels dedicated to this usage.
For example, a deployment scenario described in SDD (fig. 3) is shown below. This “aggressive” deployment scenario suffers from interference at the intersection of “red” and “blue” passes, which conduct to low data rate or lack of coverage.

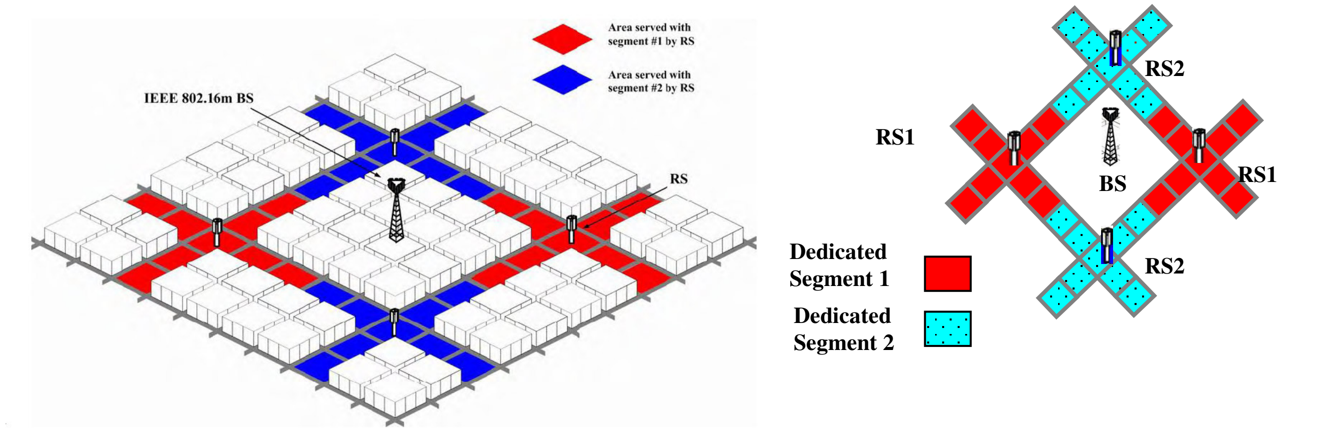

Fig 3: SDD example for aggressive segment reuse

A better spectral efficiency and coverage will be obtained if dedicated and shared segments will be introduced. In fig. 3 there are areas around the RS cell center which can be reused in parallel. We introduce in fig. 4 the idea of the Shared segment. The reused spectrum can be appreciated from fig. 4:

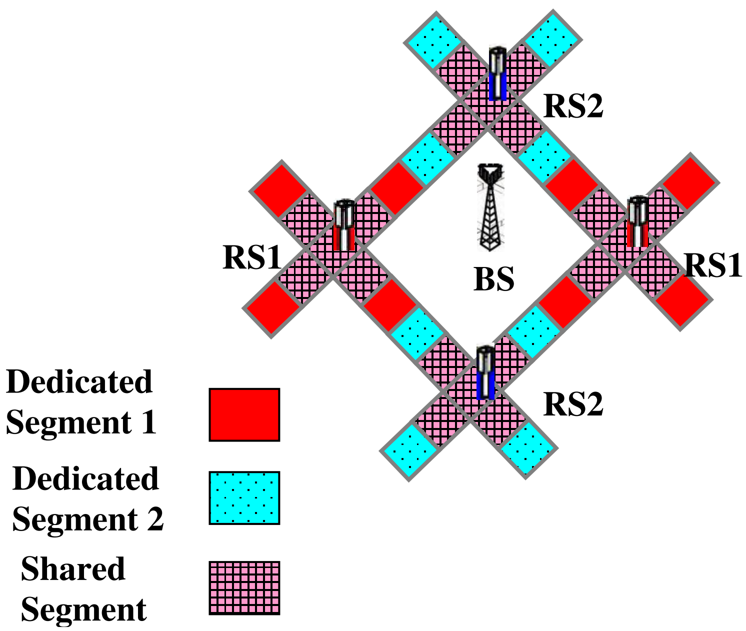

Fig. 4 Usage of dedicated and shared segments in Relay operation

If we make the simplified assumption that used spectrum is reflected by the coverage, in fig. 3 are used 9*2=18 squares while in fig. 4 are used 1+1+5=7 squares, **representing a 18/7 = 250% better spectrum efficiency.** So the use of the Shared segment may significantly increase the spectral efficiency. Usage of the dedicated segment will make possible the increased cell size.

Proposal

__Insert text for SDD, clause 11.4.4__ **Relay Support in Frame Structure**

Relay operation

11.4.4.1 TDD operation

The TDD Relay will never transmit (Tx) and receive (Rx) in the same time.

Time partition 1 (BS-Tx, RS Rx)

The functional description of the BS/Relay operation during time partition 1 is given in the figure 5. It can be seen that the Relay is the focal point of the Receive (Rx) activity.

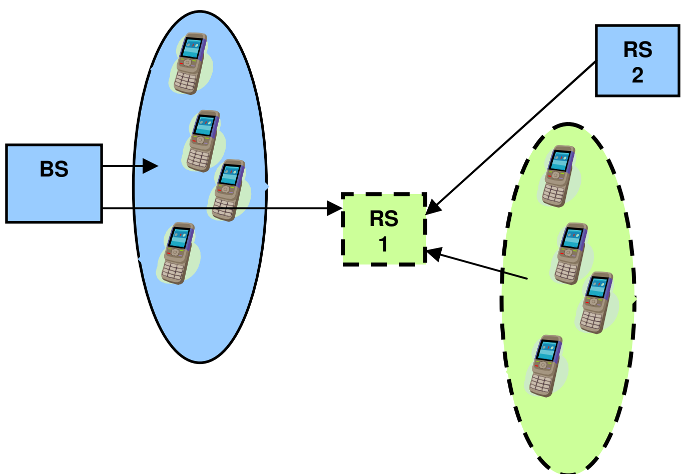

Figure 5 Operation during time partition 1 - TDD

This time partition includes the following segments:

- One DL Segment which carries the BS traffic. This segment will be able to carry at least two different STC (space-time coding)/MIMO modes: one for BS-SS communication and one for BS-RS communication. This segment may be preferably split in two segments, each one using a different STC/MIMO mode. During the BS DL transmissions the RS is in the Receive Mode.

- UL Relay Segment carries:

  - Up-link traffic from the SSs (relay access mode)
  - Backward link of the next hop RS.

This segment may be either split in dedicated and shared sub-channel groups or alternatively different segments may be allocated to the dedicated and shared UL RS traffic. BS downlink traffic may be also scheduled during the shared part of the Relay segment, if it will not create interference.

The RS is isolated in the access activity (RS-MS) from the BS due to the different used sub-channel segment and the significant distance between RS and BS. The isolation is increased by the usage of directional antenna for the Relay access operation and feeding link (BS-RS link).

Time partition 2 (BS Rx, RS Tx)

The functional description of the BS/Relay operation during time partition 1 is given in the figure 6. It can be seen that the Relay is the focal point of the Transmit (Tx) activity.

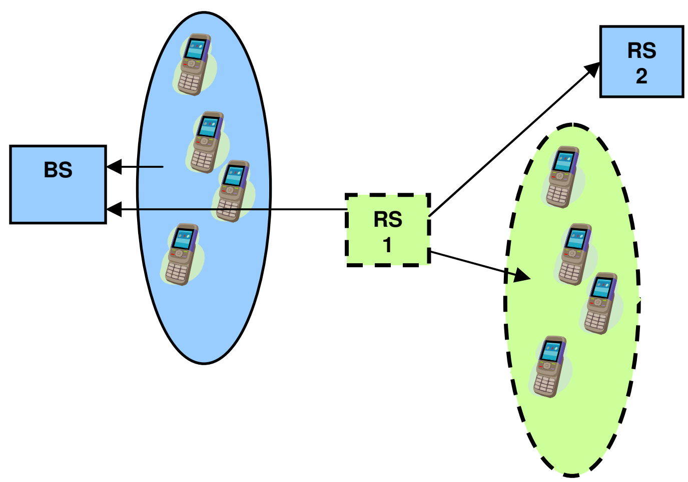

Fig. 6 Operation during time partition 2 - TDD

This time partition includes the following segments:

- BS UL Segment carries:
  - BS access traffic (SS transmissions).
  - BS-RS backward link

  This segment will carry at least two different STC modes: one for BS-SS communication (sub-channel group for BS access mode) and one for BS-RS communication. Different sub-channel groups will be allocated to this activity.

  During the BS UL transmissions the RS is in the Transmit Mode.
- DL Relay Segment carries:
  - Downlink RS access traffic to the SSs associated with it. This segment may be split in dedicated and shared segments or different segments may be allocated to the dedicated and shared DL RS traffic. The shared segment can be also used by the up-link BS activity not creating interference to Relays.
  - Forward link to the next hop RS.

There is interference potential between:

- 1. Transmitting SS to BS and the receiving SS from Relay (SS to SS interference)
- 2. Transmitting SS to Relay and the BS (SS to BS interference). This scenario is less problematic, due to the higher separation distance.

The possible isolation for the first scenario is the SS-SS separation (90-100dB in NLOS for 100m) and the segment separation (25dB for using adjacent carriers and 40 dB for using alternate carriers). If the interference still persists, the scheduling of the interfering SSs shall be done in such a way that they are separated in time domain, even if the penalty is some delay for those SS. A possibility would be to schedule the interfering SSs in different Frames. Proposal 2 resolves this potential interference.

Frame structure – Proposal 1

The following picture gives a functional description of the BS/Relay operation. The BS is considered to be in HOP 0. The first Relay is in HOP 1. The Frame partition starts with the BS DL, which is also relevant for the Relay Stations in the hop 2n.
To each functional behavior is allocated a segment in the OFDMA domain.
A Relay will transmit in two different directions in the same time. Each transmission will use the suitable segments associated to a specific antenna.
UL and DL activities are mixed inside the Frame. The permutations used for UL and DL shall be compatible, but not necessary identical.
The Frame Control Header (FCH) will be sent in all the DL segments which are intended for different MIMO/STC modes or for different antennae. The FCH may be sent at the start of the multi-frame only.
Preambles will be sent in DL but they can be sent also in up-link.

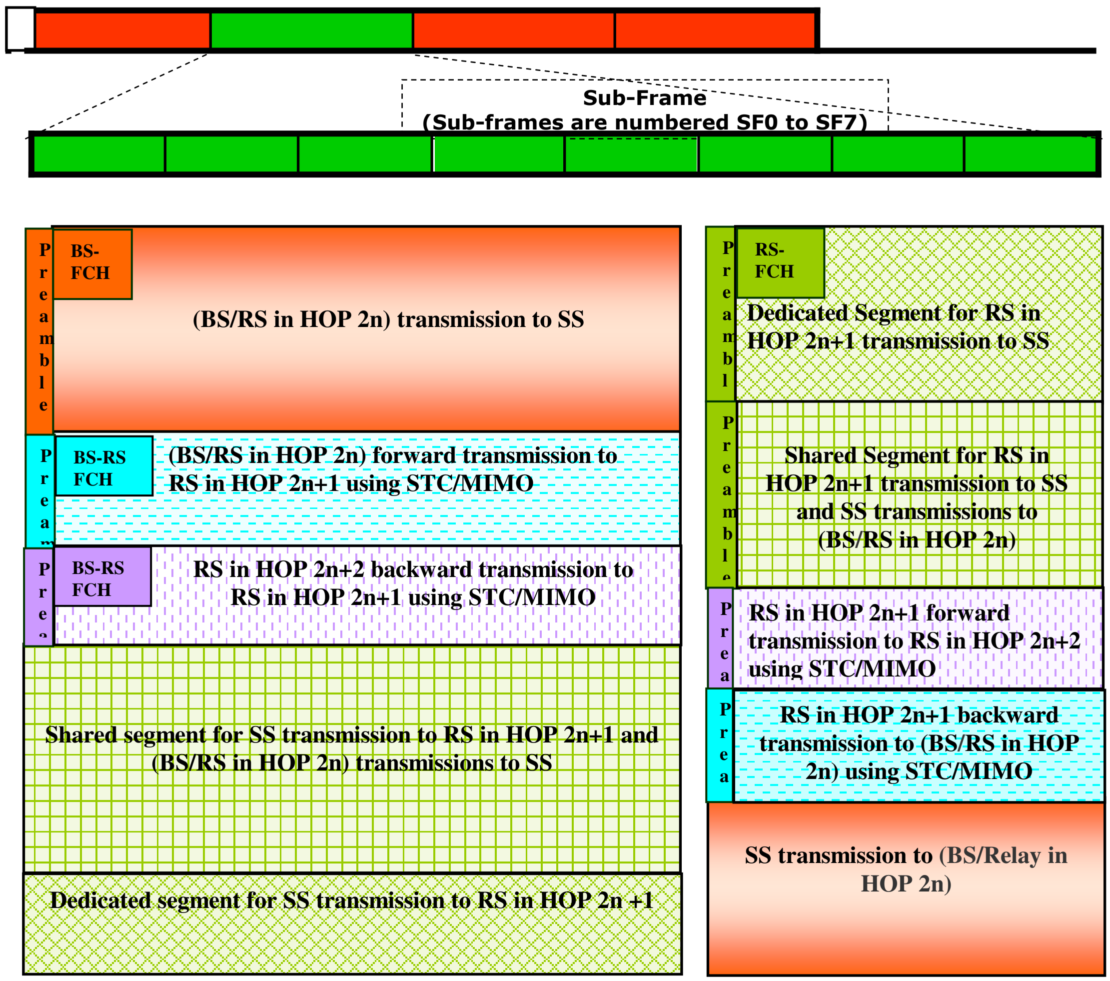

Fig. 7 TDD Frame structure for 16m Relay – Proposal 1

This scheme has the advantage of minimizing the number of switching points in Relay operation and allowing same sub-frame duration as in regular TDD operation.

Frame structure – Proposal 2

In this proposal the transmit activity for BS/RS in HOP 2n is separated in time domain from the receive activity of the Relay in HOP 2n+1. Figure 8 shows the Frame Structure.

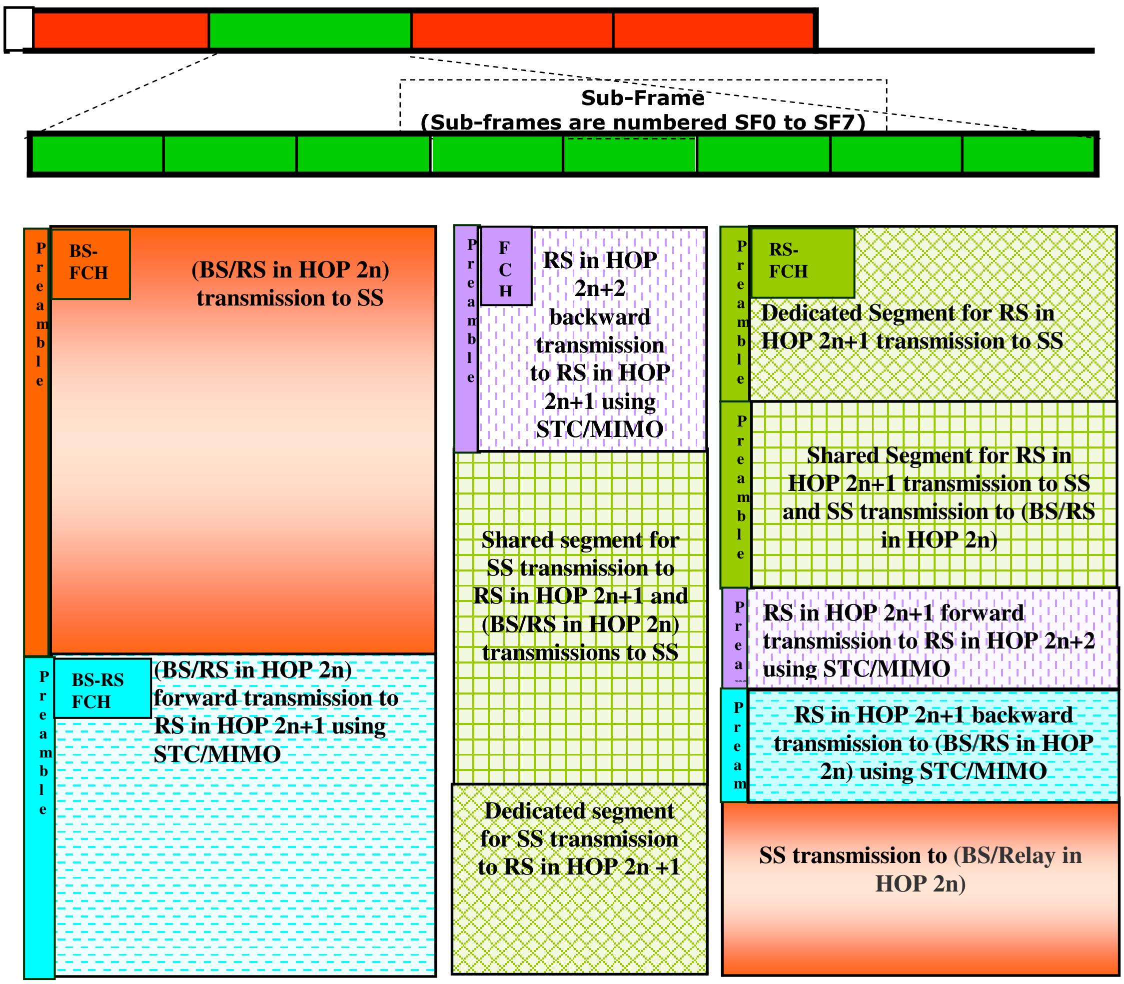

Fig. 8 TDD Frame structure – proposal 2

Multi Hop-operation

The following Table illustrates the multi-hop operation for 6 Hops.

Table 1 Propagation times

Frame 1, BS DL	Frame 1, BS UL	Frame 2, BS DL	Frame 2, BS UL	Frame 3, BS DL	Frame 3, BS UL	Frame 4, BS DL
BS->RS1	RS1->BS	RS2->RS1	RS3->RS2	RS4->RS3	RS5->RS4	RS6->RS5
	RS1 -> RS2	RS2->RS3	RS3>RS4	RS4->RS5	RS5>RS6	

As can be seen from the above table, the propagation time from BS to RS6 is only 3 MAC Frames.

Legacy support

The Legacy support (802.16j) can be always done by using an appropriate number of DL and UL sub-frames allocated for the 802.16j “Relay Zone”. The TDD Proposal 2 needs only the insertion of a “Legacy” sub-frame for up-link 802.16j operation. The DL operation in the Proposal 2 is similar with the DL operation of the 802.16j relays.

End text for SDD

Advantages

The advantages of this solution are:

- Lower MAC overheads
- Better granularity for resource allocations (in time domain the resource allocation is more or less fixed by the sub-frame size and number)
- Support for MIMO in BS-RS communication
- Significant lower data traffic forward delays; only 1 frame is needed for 2 hops. This proposal takes advantage of the new sub-frame structure, which will reduce the 802.16m latency.
- Better spectral efficiency generated by the usage of “shared segments”.