Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	Proposal for 802.16n architecture with path and frequency resilience
Date Submitted	2011-01-06
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Re:	
Abstract	This document proposes a versatile 802.16n architecture in the limits of the 802.16n PAR
Purpose	To be approved and included in SRD
Notice	
Release	
Patent Policy	
Note	Note: This work has been partially supported by the FP7 project BuNGee, ICT-248267

Proposal for 802.16n architecture with path and frequency resilience

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1 References

[1] IEEE 802.16gman-10/0038r4, "802.16n System Requirements Documents," November 2010.
[2] IEEE C802.16gman-10/61r2, Proposed Overall Network Architecture for IEEE 802.16n
[3] IEEE C802.16gman-10/63, Proposed System Architecture Reference Model for IEEE 802.16n
[4] IEEE P.802.16j/D9 Multihop relay specification.

2 Introduction

The scope of this contribution is to present some variants of possible architectures for fulfilling 802.16n targets such as **path redundancy and robust operation** and to conclude with a proposal for the general 802.16n architecture and the connectivity with other 802.16 entities.

3 Solution for BS-BS communication

The 802.16n SRD includes a requirement for BS-BS communication; however the 802.16n PAR scope does not allow PHY changes to BS. We propose to use instead the well known solution for the BS-BS communication: the addition of an HR-MS, which can be fixed of mobile, depending of the BS degree of mobility. The HR-MS is connected by Ethernet/IP to the collocated BS.

This communication solution is shown in the next figure:

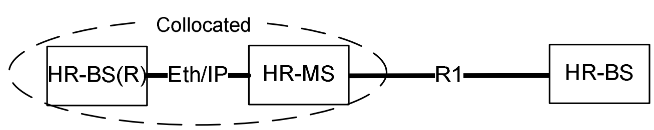


Fig. 1 Simple solution for BS-BS communication

The communication between HR-BS and HR-BS(R) is beyond the scope of this standard.

4 Solution for HR-RS

The solution in Fig. 1 is our preferred option for a fast time-to-market of 802.16n, given the essential problems presented by the 802.16j relay (see Annex A).

A network including two BSs and two relays is shown in Fig. 2.

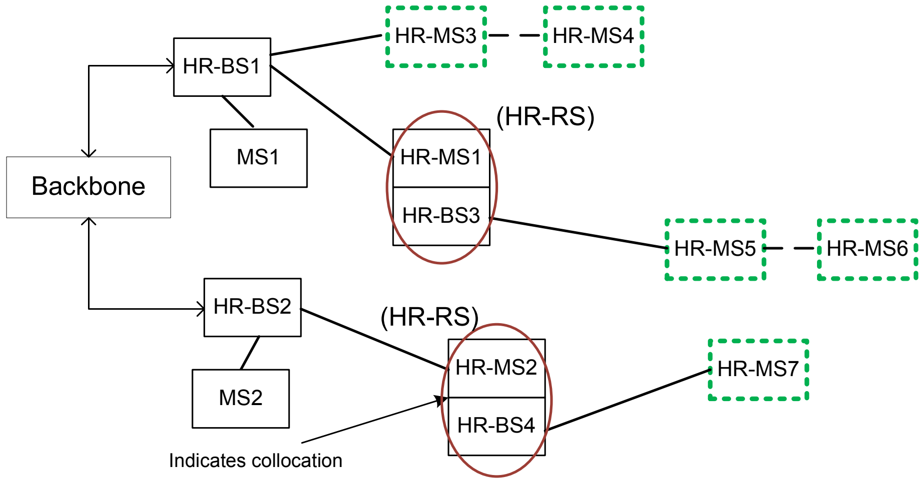


Fig. 2 Simple network with relays and MSs

The network from Fig. 2 includes only two new network entities (HR-BS and HR-MS). The network is composed from:

- Two HR-BSs connected to the backhaul
- Legacy MSs connected to these HR-BSs; in addition, HR-BS1 covers two HR-MSs, where HR-MS3 is serving as relay for HR-MS4.
- Two HR-BSs operating as relays, the connection to the first hop HR-BS being done with HR-MSs
- HR-MSs connected to the second-tier HR-BSs.

5 Network path resilience

Now let's demonstrate the property of high path redundancy for the network in Fig. 2.
Fig. 3 shows all the possible paths based only on the MS-MS direct communication.

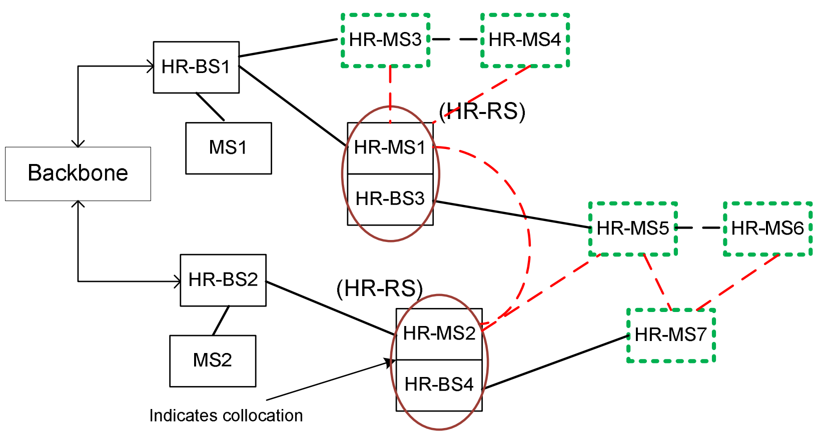


Fig.3 Multiple paths based on MS-MS direct communication

The most important path in Fig. 3 is the HR-MS1 to HR-MS2 communication, because due to this path the failure of one HR-BS in each hop can be recovered by the network.

In Fig. 4 is shown that, even if one BS in the first hop and one BS in the second hop become unfunctional, all the HR-MSs in the network remain connected to the backbone.

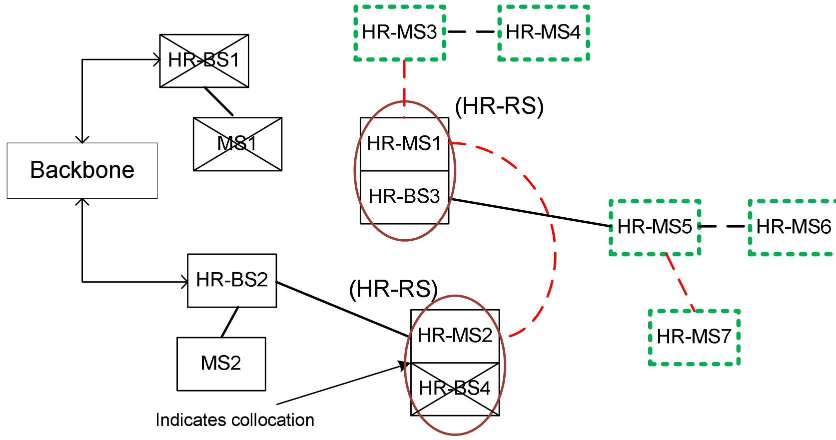


Fig. 5 Network resilience

An essential element for enabling the network resilience in real deployments is the coverage provided by the HR-MS. The maximum coverage can be provided only by the sub-channelization defined for the uplink MS transmission, implying that this OFDMA sub-channelization shall be used for the direct HR-MS communication in both directions. It should be noted that the coverage provided by the BS DL PHY mode provides coverage at the expense of a much higher transmission power, not available for a mobile subscriber.

6 Combined use of two frequency channels

While the solution in fig. 5 has a good connectivity property, the capacity of this network is seriously diminished by having a high number of links in the same frequency channel. Based on the experience of the 802.16j and 802.16m relays, at the end each link may require a different time slot, while relaying the same traffic, such that using the in-band relay solution is not improving the system capacity and in multi-hop case will certainly diminish it.

6.1 Multi-frequency relays

An improved approach for increasing the system capacity is the simultaneous usage of two or more frequency channels. Each frequency channel may be located within the same or within different spectrum bands, some examples being listed below:

- Two channels in licensed bands
- One channel in a licensed band and another one in a LE band
- Both channels in LE bands
- Two channels in licensed bands and one channel in LE bands.

6.1.1 Different frequencies in each hop

The simplest possibility to increase the system performance, while using a two hop relay, is to allocate different frequencies for the first and 2nd hop, preferable each frequency being within different and not adjacent frequency bands, for eliminating the reciprocal interference.

A resulting network example is shown in Fig. 6. While using two frequency channels, the frequency allocation may be done such to use f1 in the first hop, f2 in the 2nd hop and again f1 for inter HR-MS communication in the 2nd hop (the assumption is that there is enough space separation for avoiding the interference between the first hop and the direct communication links) .

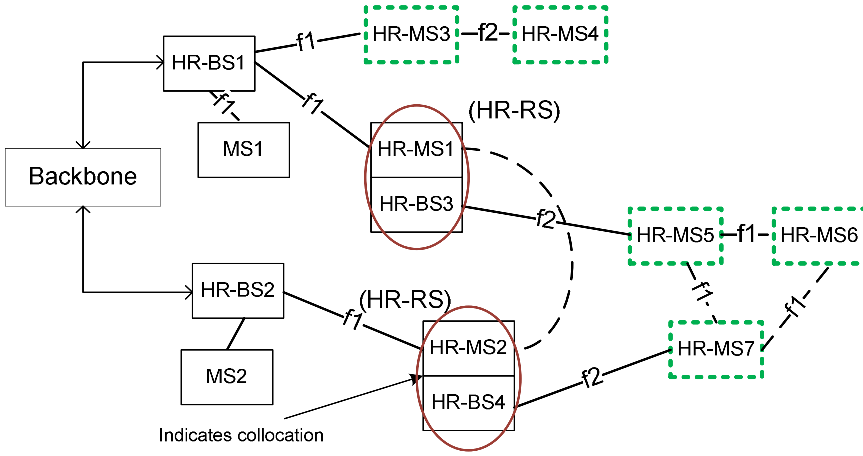


Fig. 6 Different frequencies in each hop

6.1.2 Multi-frequency relay

Fig. 7 shows a two hop system, where in the first hop there are two Base Stations, each using a different frequency band. The HR-BS3 backhauling is done through two MSs, each associated with one of the BSs in the first hop through the regular R1 interface. We call the resulting entity a multi-frequency relay (HR-MF-RS).

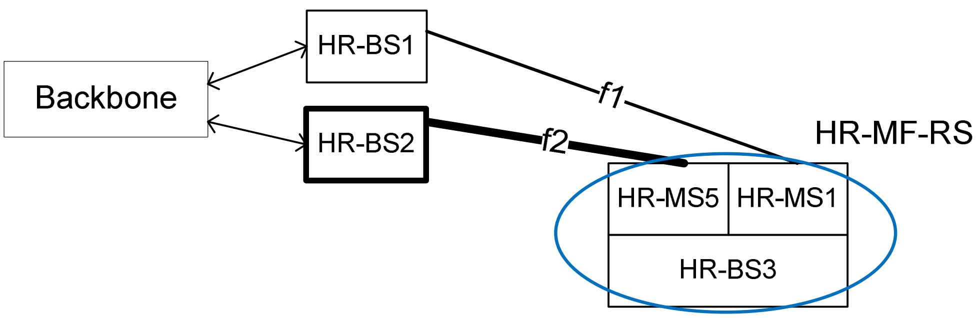


Fig. 7 Multi-frequency relay

The capacity of the relay link is obviously increased by the usage of aggregated frequency channels, where the two channels can be placed in two or more different bands. This solution also enhances the system resilience, as the data transmission for the relay link has a double path.

6.1.3 Multi-frequency direct communication

The capacity of the system can be further increased if some of the direct-communication links are transferred to a frequency which is different from the access frequency. Such system behavior is desirable for different reasons, like increasing the capacity or avoiding the interference between the regular access links and the direct-communication links. It should be noted an interesting property of the LE spectrum, related to coverage:

- The cell size in uplink, due to the OFDMA gain of the sub-channelization per MS, is not influenced by the general power limitations (30dBm e.i.r.p. instead of 60dBm e.i.r.p.) characteristic for the LE spectrum.

6.2 Multi-frequency system architecture

The system architecture presented in Fig. 8 uses in a more flexible mode the available spectrum, licensed and LE, for increasing both the resilience and the system capacity.

The advantage of this approach is that if a HR-BS in the first hop fails, the remaining HR-BS can cover the entire network on its operating frequency, such that there is no increase in the number of direct communication links.

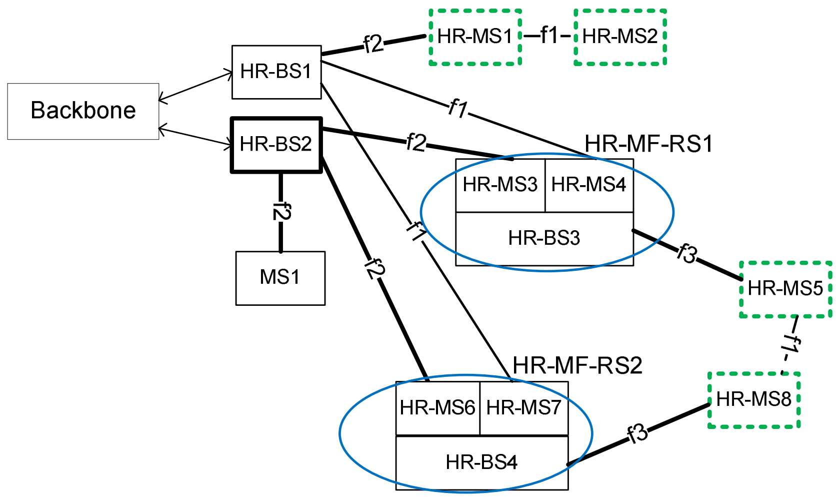


Fig. 8 – Multi-frequency system architecture

A sounding frequency allocation is using f1 within a LE spectrum and f2, f3 within the licensed spectrum. We emphasize again that the coverage of the OFDMA UL sub-channelization has high gain, such that the power limitations of the LE spectrum is not relevant. For example, relatively similar coverage will be provided in 3.6GHz for access and 5.4GHz for the direct HR-MS links.

7 Network reference model

The network reference model for the proposed architecture is based on the diagrams in the contribution IEEE C802.16gman-10/0063, while emphasis on the internal structure of the HR-RS and the possibility for multi-frequency operation.

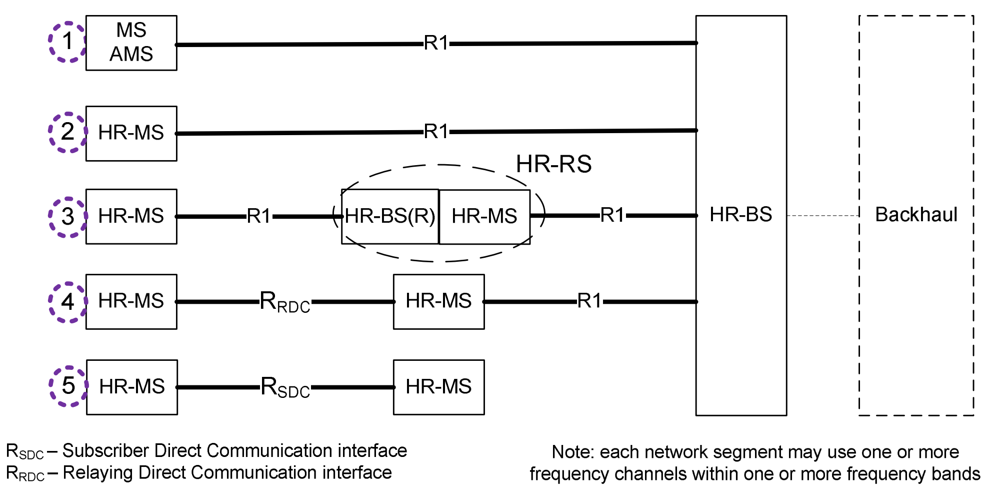


Fig. 9 Network reference model

8 Inter-connection table

The interconnection table is a good instrument for analyzing the commitments of the 802.16n Task Group relative to the back-ward compatibility with the 802.16 specification. However, we have a number of serious concerns regarding the compatibility between the 802.16n PAR and some of the 802.16 specifications.

Specification problems:

1. Annex A of this contribution shows significant coverage problems of the 802.16j specification (in fact only the TTR not-transparent), such that we consider the 802.16j relay as being incompatible with the 802.16n PAR requirements, including "alternate radio path establishment in degraded network conditions".
2. 802.16m/D10 specification has essentially the same problems as 802.16j, because is using the STR and TTR modes (see Annex A).
3. We believe that the situation will change in 802.16p, in which may be given more liberty for the frame repetition pattern due to additional silence periods.

Our proposal for the inter-connection table is to delete the non-relevant or obvious fields and to add 802.16p BS and 802.16p MS (IEEE C802.16gman-10/0061r2 was used as reference). The deleted content is either not relevant for the 802.16n specification or it is obvious.

HR-BS	HR-RS	HR-MS	16p-BS	16p-RS	16p-MS	ABS	ARS	AMS	BS	MR-BS	RS	MS	
			n/a	t.c.	t.c.	n/a	n/o	16m	n/a	n/a	n/o	16-2009	HR-BS
			t.c.	t.c.	t.c.	16m	n/o	t.b.d.	n/a	n/o	n/o	16-2009	HR-RS
			t.c.	t.c.	t.c.	16m	n/o.	n/a	16-2009	n/o	n/o	n/a	HR-MS
													ABS
													ARS
													AMS
													BS
													MR-BS
													RS
													MS

n/o – not supported or optional
t.c. – to coordinate

9 Text for SRD

<u>Insert the following text:</u>

Annex A System architecture, reference model, connectivity table

A1. System architecture

The 802.16n system architecture has as scope to provide "alternate radio path establishment in degraded network conditions". We have identified the following possibilities to establish alternate paths, while allowing only OFDMA PHY changes "for enabling operation with radio path redundancy and direct communication between subscriber stations".

Mode 1: Path redundancy based on MS-MS communication

The architecture in the following figure allows path redundancy between different HR-RSs and HR-MSs by making visible the HR-MS side of an HR-RS. In case of failure of a HR-BS and/or HR-RS, it will be found a communication path using the MS-MS direct connection.

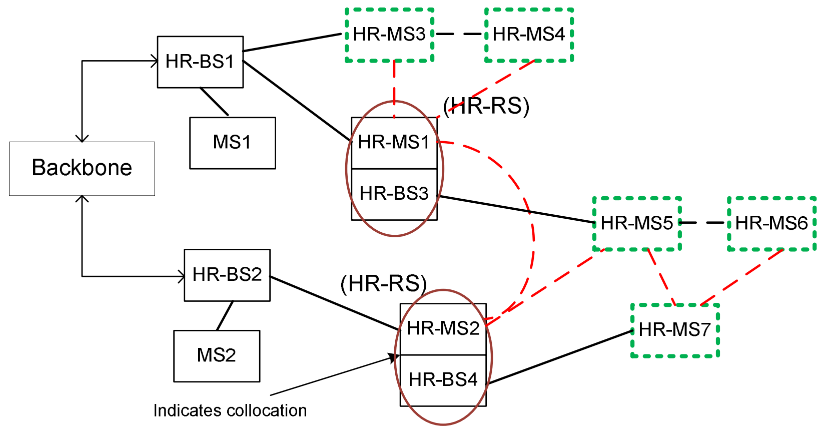


Fig. A1 Path redundancy based on HR-MS direct communication

Mode 2: Path redundancy based on parallel operation in different frequencies

Another possibility for obtaining path redundancy is the usage of multiple frequency channels, within Licensed and/or LE spectrum, simultaneously or only in case of failure. It is preferred, for reducing the interference, using frequency channels located within different non-adjacent frequency bands. This operation mode, when more spectrum is used simultaneously, allows for higher system capacity as well.

Fig. A2 shows possible system architecture.

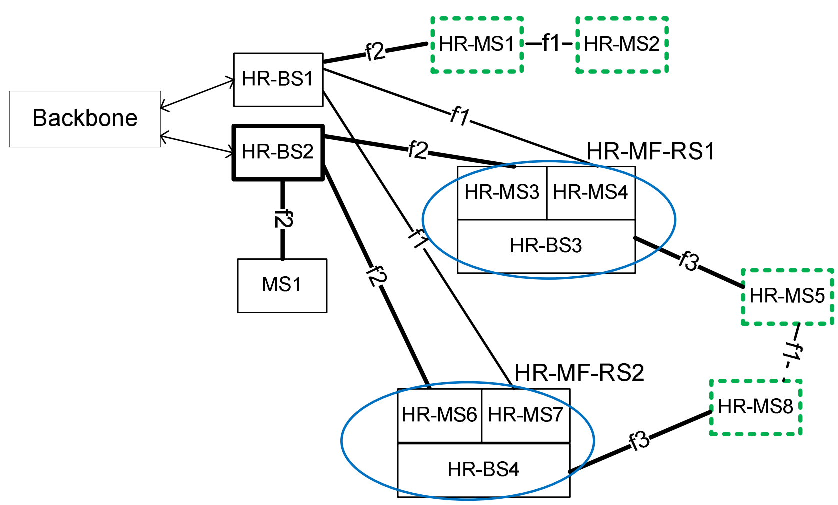


Fig. A2 Path redundancy based on usage of multiple frequencies

A relay able to operate in a multi-frequency mode is named HR-MF-RS. As can be observed in Fig. A2, each HR-MF-RS relay may use two different frequency channels for the relay link to the HR-BS. In addition, the direct communication HR-MS links can also use frequencies different from those used in access.

A2. Reference model

The reference model of the 802.16n system is shown in fig. A3.

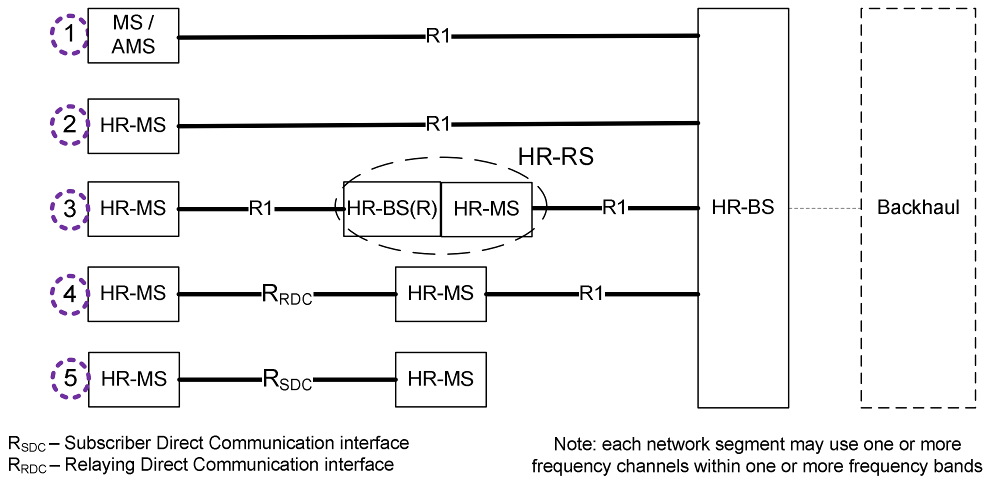


Fig. A3   System reference model

The following radio interfaces are defined:

R1: radio interface between HR-BS and HR-MS, supporting also the HR-BS communication with MS (IEEE P802.16-2009) or AMS (IEEE P802.16m).
R_{RDC}: radio interface between HR-MS and a relaying HR-MS, the last one being connected to the infra-structure
R_{SDC}: radio interface between two HR-MS s in the absence of the infrastructure.

A3. Interconnection table

The following table shows the interconnections between the 802.16n system elements and system ele-ments defined in other 802.16 specifications or drafts.

	16p-BS	16p-RS	16p-MS	ABS	ARS	AMS	BS	MR-BS	RS	MS
HR-BS	n/a	t.c.	t.c.	n/a	n/o	16m	n/a	n/a	n/o	16-2009
HR-RS	t.c.	t.c.	t.c.	16m	n/o	t.b.d.	n/a	n/o	n/o	16-2009
HR-MS	t.c.	t.c.	t.c.	16m	n/o	n/a	16-2009	n/o	n/o	n/a

where:
n/o – not supported or optional
t.c. – to coordinate
16p-BS – Base Station as amended by 802.16p
16p-RS - Relay Station as amended by 802.16p
16p-MS - Mobile Station as amended by 802.16p.

End of inserted text

10 Annex A: Limitations of the 802.16j relay

In continuation are exemplified the problems of the 802.16j specification, in relation to the 802.16n PAR.

The 802.16j RS can work using two scheduling modes, for each one being associated a specific frame structure. In continuation we will present our analysis of the two modes, concluding with the very limited applicability of the transparent mode in the same radio frequency band, and the coverage problem of the non-transparent mode.

10.1 Relevance

In clause 1.3.4 (Air interface nomenclature and PHY compliance) of 802.16j/D9 is stated that the **802.16j specification is limited to licensed bands**, while the 802.16n covers also LE bands. This is an important limitation, due to the fact that many bands of relevance are either light-licensed (shared) or LE. The 802.16n PAR clearly mentions the usage of both licensed and LE bands, but unfortunately 802.16j does not support this requirement.

Another limitation is the operation in **TDD mode only**, as some of the licensed bands can use the FDD duplexing.

10.2 Full-duplex TDD (STR) in non-transparent mode, same band

Definitions:
"3.121 simultaneous transmit and receive (STR) relaying: a relay mechanism where transmission to subordinate station(s) and reception from the superordinate station, or transmission to the superordinate station and reception from subordinate station(s) are performed simultaneously.

3.122 STR RS: a **non-transparent relay station** capable of performing STR relaying."

We question the viability of the "full duplex TDD concept", on the same or adjacent carrier frequencies. The following calculations indicate that the interference created by the transmitting radio into the receiver circuits makes this operation mode un-usable.

Assuming a RS transmit power of 30dBm and an antenna isolation of 40…70dB, where 40dB is applicable in the case of omni antennas (typical case) and 70dB is applicable for the case of back-to-back, vertically mounted directive antennas, the interference caused by the SS transmitter into the BS receiver is:

23dBm – (**40dB**…70dB) = **-17dBm**…-47dBm (**RS saturated when using omni antennae**!!!)

The saturation levels for the RS are actually not defined in 802.16j, but we assume that they are similar with the MS and BS levels, for the respective sides of the relay. 802.16-2009 defines the levels as:

"**8.4.14.3.1 SS receiver maximum input signal** The SS receiver shall be capable of decoding a maximum on-channel signal of –30 dBm
8.4.14.3.2 BS receiver maximum input signal The BS receiver shall be capable of decoding a maximum on-channel signal of –45 dBm."

The interference caused by the RS (BS) into itself (MS) is dependent of the RS transmitting power. For an average value of -33dBm, this interference is:

33dBm – (**40dB**…70dB) = **-7dBm**…-37dBm (**RS saturated when using omni antennae**!!!)

It is obvious that the STR relay has a very low chance to work in this mode, within the same frequency band, and it should not be considered as a solution for 802.16n.

10.3 Full-duplex TDD (STR) in non-transparent mode, different band

The simultaneous Tx and Rx operation in different frequency bands does not have the problems shown above. However, the way in which the relay operation is defined in IEEE P802.16j, clause **8.4.4.8.3, allocates a full frequency channel solely for the communication of an RS with a BS, i.e. for each RS will be needed a different additional frequency channel.**

In addition, the coexistence with the TTR relay has as consequence the split of the UL sub-frame in the time domain, creating the **same coverage and performance problems as by the TTR relay**, by using in a non-efficient mode the second frequency channel.

10.4 Half-duplex TDD (TTR) non-transparent relay mode

Now we will analyze the TTR non-transparent relay mode. TTR is defined as:

"**3.123 time-division transmit and receive (TTR) relaying:** a relay mechanism where transmission to subordinate station(s) and reception from the superordinate station, or transmission to the superordinate station and reception from subordinate station(s) is separated in time.

…..

3.126 TTR RS: a non-transparent relay station which performs TTR relaying."

The frame structures for this mode are shown below.

….

8.4.4.8.2 Frame structure for non-transparent TTR mode

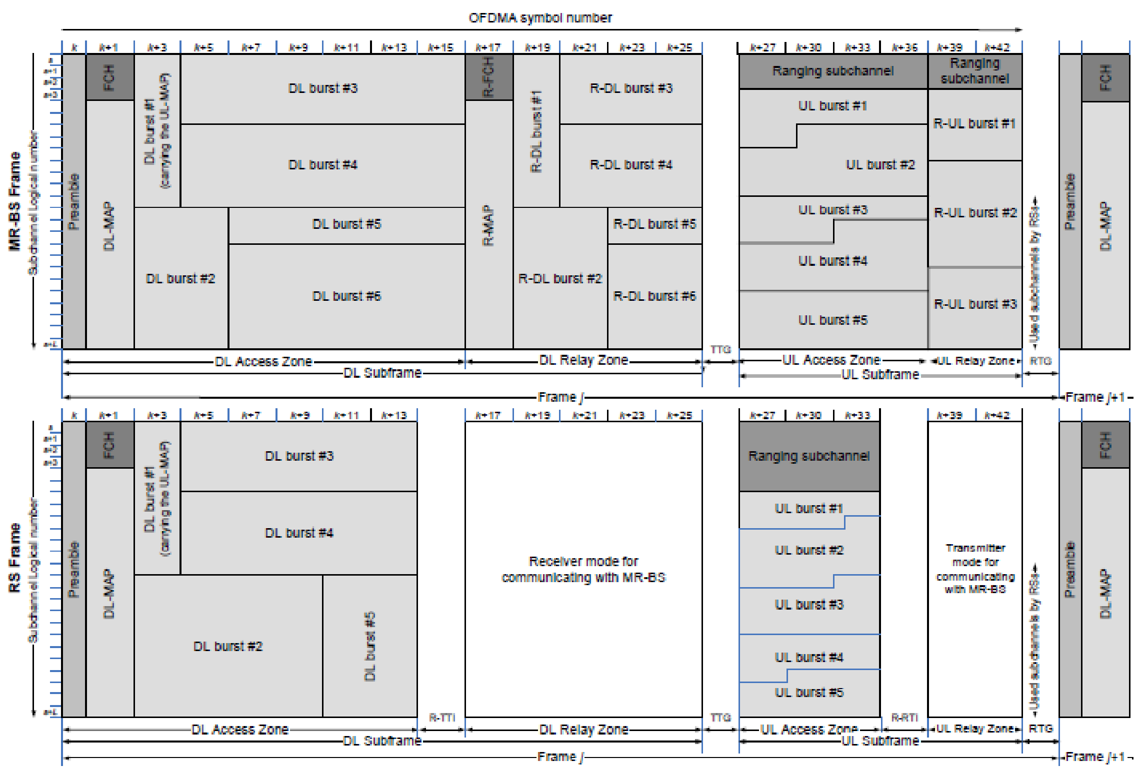


Figure 234c—Example of minimum configuration for a non-transparent TTR relay frame structure[2] "

This mode of operation suffers from the split between the UL access zone and the UL relay zone, reducing the cell size and the performance of the both MR-BS and RS.

10.5 802.16j transparent mode

This operation mode **has very reduced performance** also. See the arguments below.

"8.4.4.8.1 Frame structure for transparent mode

Insert new sub clause 8.4.4.8.1.1:

8.4.4.8.1.1 MR-BS frame structure

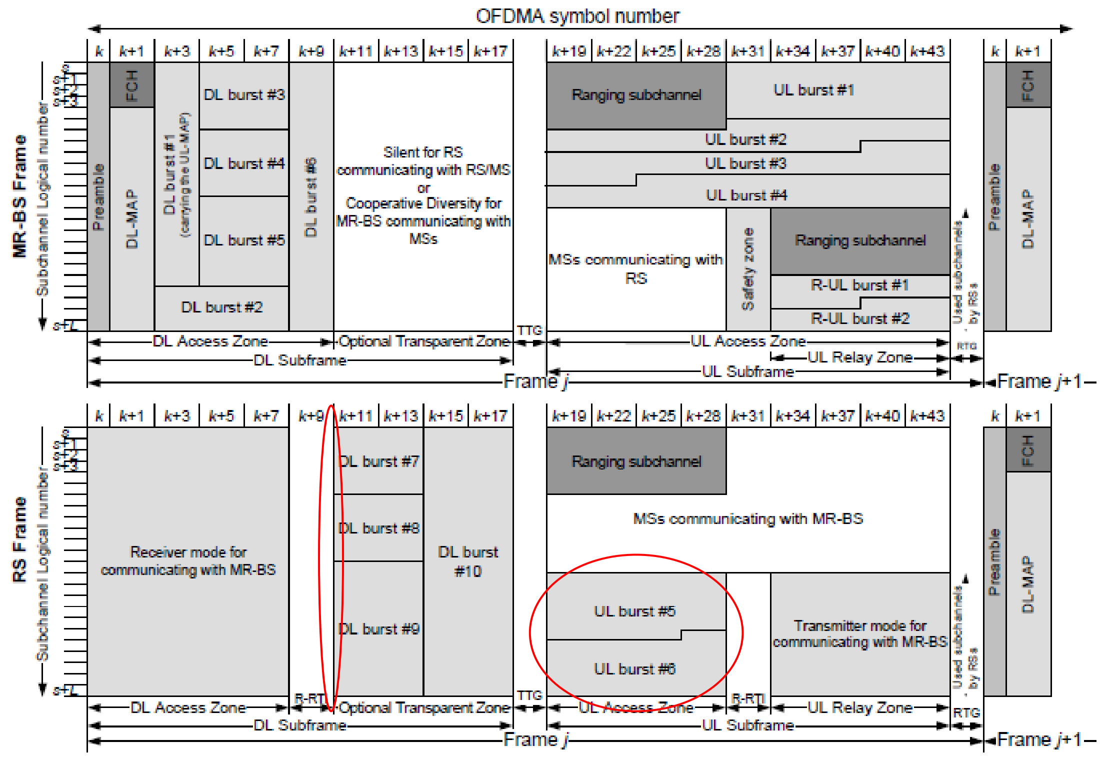
An example of the MR-BS frame structure is shown in Figure 234a. Each frame in the downlink transmission begins with a preamble followed by an FCH, DL-MAP, and possibly UL-MAP. **R-MAP is located following MAP or defined as an extension of MAP**.

….

8.4.4.8.1.2 Relay frame structure

…..

A transparent RS does not transmit the preamble, FCH and MAP at the beginning of the frame. Instead it receives the preamble, FCH and MAP and optional R-MAP transmission from MR-BS."



igure 234b—Example of configuration for a transparent relay frame structure : MR-BS and RS have partitioned UL subframe in the frequency domain

As indicated in the text above, only the BS transmits the preambles. The lack of preambles (see the red marking in the above figure) transmitted by the RS has as consequences reduced DL range and in general much reduced performance. The reduced range and performance are also characteristic for the UL, where the relay bursts have much lower duration (see the duration of the UL burst in the above figure).

The range is also reduced by the fact that a MS shall decode the RS-MAP sent by the BS.

In fact, if the MS is able to decode the MAPs, why an RS is actually needed?

10.6 Conclusion

The 802.16j specification does provide only one viable mode for operation within the same frequency band: non-transparent TTR (half-duplex). This mode has however the disadvantage of the UL frame split in the time domain and by this the reduced cell size for both MR-BS and RS.