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| Re: | Comment in 802.16d Sponsor Ballot | |
| Abstract | It is proposed a simple communication protocol for spectrum sharing, in LE bands | |
| Purpose | Provide a certain grade of guaranteed QoS in LE environment and better spectrum use | |
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# Spectrum sharing in License Exempt bands – protocol proposal

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## Introduction

For IEEE 802.16 systems it is important the use of License Exempt bands, especially the 5.8GHz band, where higher power is allowed. However, the operators are scared by the use of LE bands, due to failure of 802.16 standards to define interference avoidance mechanisms.

The IEEE 802.11 standards define “listen-before-send” or “clear channel assessment”, that proved to be a good sharing mechanism for WLAN systems. However, this mechanism does not provide QoS and does not work in 802.16 access environment, due to the fact that 802.16 systems use scheduling.

The interference will mess the offered services when:

- Co-located or almost co-located Access Points use un-synchronized MAC Frames; this is a general TDD problem, creating BS (Base Station)-to-BS and ST (Subscriber Terminal) to BS interference
- Subscriber Terminals, associated with Access Points belonging to different operators, have un-coordinated transmit and receive intervals; they may be almost co-located and strongly interfere, even when using different frequency channels (adjacent channel interference)
- Different operators use not co-located Base Stations; the ST working in the nearby of another Base Station will be strongly interfered (see fig. 1).
- Different operators have partially overlaid cells and use the same channel.
- Indoor ST is in the relative vicinity of a WLAN network (see fig. 2).

Regulators, as FCC, will limit the power in order to reduce interference and give users a fair access to the spectrum.

Came the time that standards will look to solutions that can resolve the QoS problem and allow regulators to increase the transmitted power.

This paper contains a proposal for such a mechanism, offering increased protection. The proposal is made for the OFDM PHY, but actually can be applied by all the 802.16 PHYs.

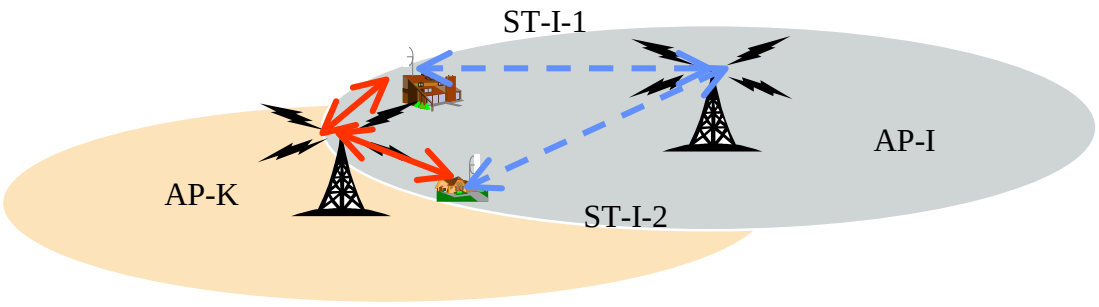


Figure 1 - Two Radio Networks, overlaid and NOT co-located

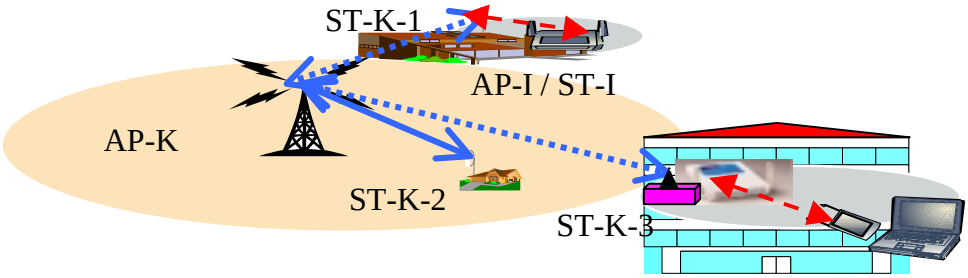


Figure 2 - Three radio networks partially overlaid

## Basic principles for spectrum sharing

As a basic condition for sharing in TDD, basic coexistence principles should be implemented:

- MAC Frame synchronization and Tx/Rx synchronization

For access systems, the simplest way to realize it should be based on operator co-ordination and system management; in order to achieve a simple sharing mechanisms, only a minimum set of dynamic controls will be defined;

This proposal further allows to:

- Create interference-free slots, in time domain, for every radio unit. Every Access Point should have equal rights to create for itself an interference free time slot. In order to achieve this, the Access Point should be able to send short commands to the other Access Points, controlling transmission in cells that create interference.

Fig. 3 shows a rotating wheel, in which every Access Point in turn, will send commands to the others.

Further principles applied here are:

- There is no external co-coordinator of the wheel movements and the number of the wheel states will be agreed by operator co-ordination, and programmed through the management mechanism;
- Every wheel state will be described as a 802.16 MAC Frame, all the MAC frames having the same duration of DL (downlink) Tx (transmit) and DL Rx (receive) intervals.
- Synchronization of Tx/Rx intervals will be preferably done by using GPS controllers; An AP that has no GPS controller will synchronize its MAC Frame with already deployed networks; if is the first to be deployed in an area, will work free-running until a GPS controlled AP will appear.
- Only adjacent channel interference will be considered; for the second adjacent channel, filters should clean the spectrum.

### *Tx/Rx splitting*

Tx/Rx splitting may be:

- Programmed by operators, after co-ordination, and changed only by management
- Dynamically changed, based on same kind of signaling as described below.

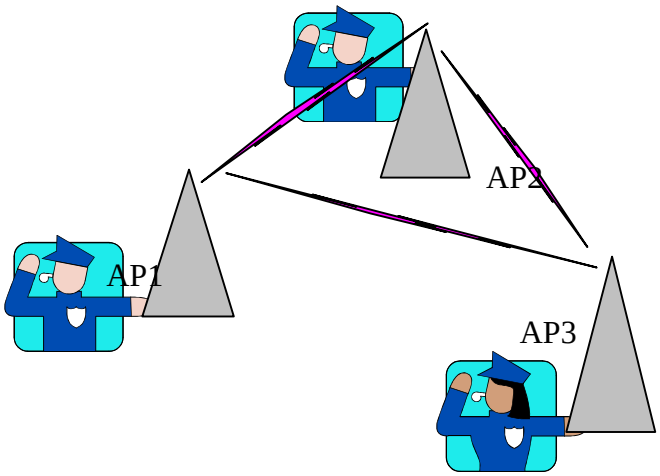


Figure 3 – Every Access Point tries to create an interference free interval

## More detailed description

### *MAC Frame pattern*

Lets take a simple example, based on the following deployment case: an operator use omni APs, and the systems operating on adjacent channels may induce interference

A cycle on N MAC frames is defined. In the continuation, the example will use N=3.

Lets consider the system working on F3, in fig.4. The MAC Frame 1 has a different structure. This structure repeats itself after 3 MAC Frames, and appears again in MAC Frame 4.

The scope of this proposal is to create periodically interference free periods, as the slots C and F in MAC Frames 1 and 4.

The system working on the frequency F3=Fn, transmits from time to time the Frame Sync_MARKER in MAC Frames 1, 1+N, 1+2N, etc. In the same frames control signals can be inserted on interfering channels (fig.5).

In the frames of type 1+kN, there are 2 slots, for every Tx or Rx period (fig.4):
- Slot B1 and E1, not experiencing interference;
- Slots C and F, when interfering channels are not operating.

In the other MAC Frames there are only slots not experiencing interference. The duration of activity of the system using F3 will be controlled by the systems using other channels, by the insertion of control signals at the end of the MAC Frames.

In every one of the slots will be transmitted the downlink MAP (same principle as used for AAS).

## *MAC frame synchronization MARKERS*

To allow for synchronization, MAC frames shall be identical.
Should be  is a known set of allowed MAC frame durations; the actual value will be picked by operators, who should co-ordinate each other.
The MAC frame starts synchronously with GPS marker for seconds, with the Tx activity.
In order to notify what kind of sync is used, at regular intervals the AP will insert SYNC_MARKERS before the frame start. Different MARKERS shall be defined:

- AP using GPS for sync will insert SYNC_MARKERS type 1
- AP that synchronize its frame after another AP will insert SYNC_MARKERS type 2
- AP free-running will insert SYNC_MARKERS type 3.

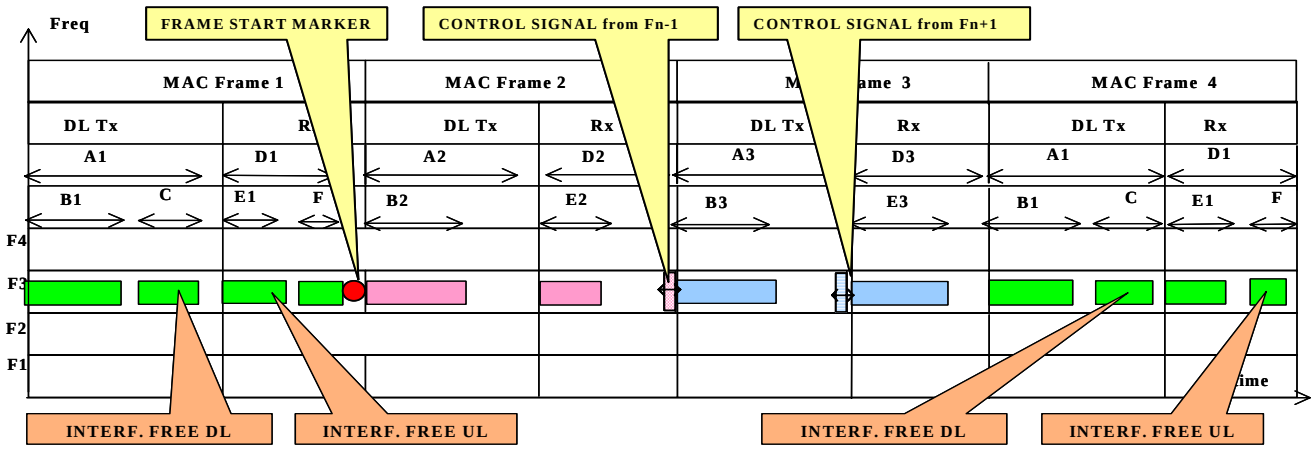


Figure 4- Time domain description

## *Rotating wheel - downlink*

In Fig. 5 is described the control signals activity, having as scope to create interference free slots.

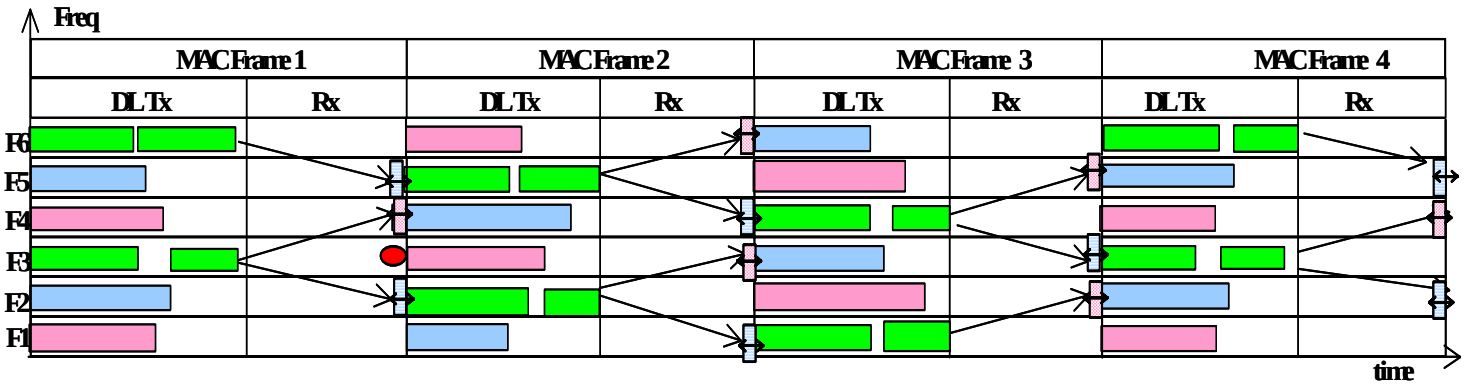


Figure 5 – Controlling down-link interference

Lets consider the activity of the system working on F3:

- in MAC frame 1 tries to create a “interference free” slot C:
  - should limit the transmissions of the systems working on F2 and F4;
  - system on F3 asks, using control messages / signals to be described below, the systems on adjacent channels to reduce the duration of their transmission

- in MAC Frame 2, it is its turn to reduce transmissions, at the request of system operating on F2

- in MAC Frame 3, the system will reduce transmissions at the request of system operating on F4.

Should be an operator agreement regarding the minimum transmission time in slots like Bk, Ek. Alternatively, the implied systems may allow then increase of transmission times, depending on the experienced interference and data traffic. For example, if this time is 50% of down-link frame, a system will be able to use (50%+50% +100%) / 3 = 67% of the time resource.
The operation without interference will be limited to 50% / 3 = 17%.

Same behavior will have systems on F2,F5, with one MAC Frame delay, and systems on F1, F4, with 2 MAC frames delay.

## *Down-link co-channel interference*

Even in FDD or with synchronized Tx/Rx periods, may be BS to ST co-channel interference, when two operators use the same frequency in adjacent geographical areas.
Through operator co-ordination process, it is possible to agree using N=4 and distribute the use of slots C, B2 and F, D between operators. The new MAC frame arrangement is shown in fig. 6. The SYNC_MARKER will be inserted only by one of the systems working on the same frequency. If System 2 will insert a control message / signal instead of the SYNC MARKER, System 1 will understand that this control signal is intended for himself.

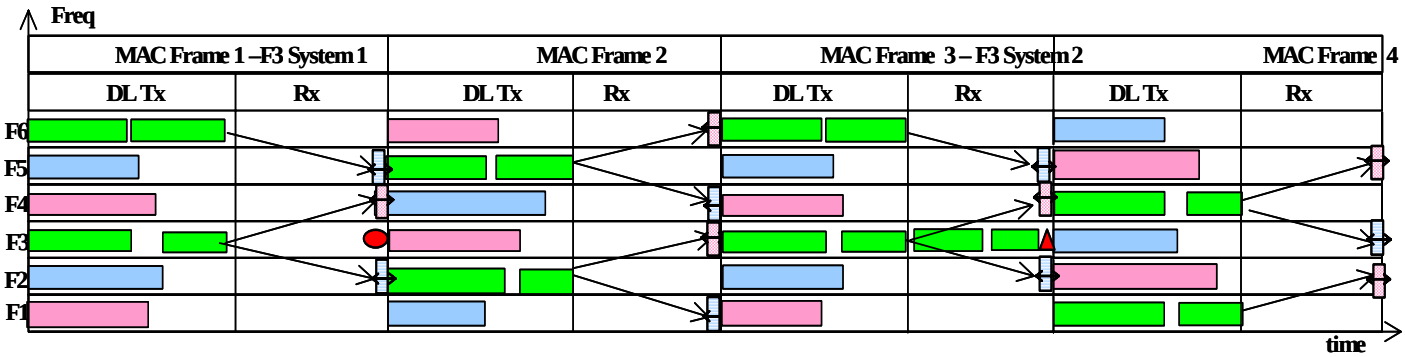


Figure 6– Possible downlink Tx arrangement for N=4, co-channel interference

## *Up-link interference*

The up-link interference is determined by temporary transmission of STs belonging to other systems, and located in the AP vicinity or transmitting with high power.

Same scenario as explained for downlink is applicable; fig. 7 shows the MAC Frame arrangement.

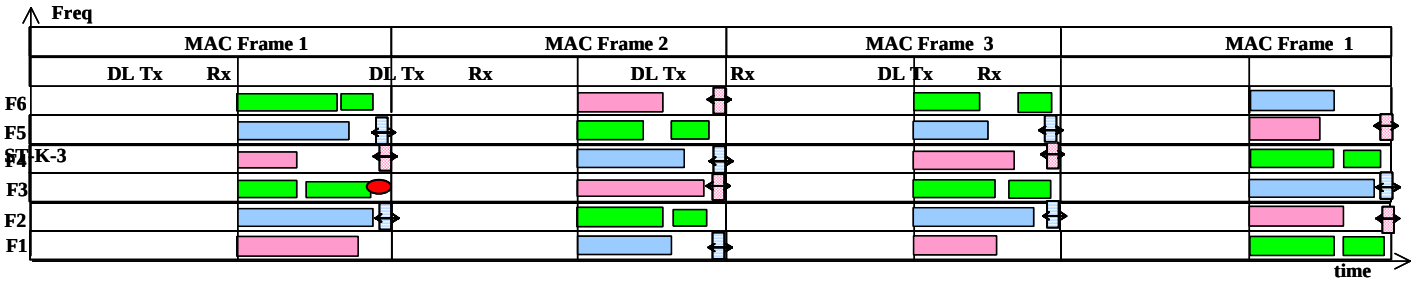


Figure 7 – Possible up-link arrangement for N=3

## Signaling procedure

### *Signaling procedures*

The signaling can use messages, or PHY signaling, using carriers, similar with procedures used in "focus contentions". The use of PHY signaling, based on inserting energy in different band zones, can make this protocol "PHY independent".

### *Message content*

For interference control, the following MAC Management messages are proposed:

| Type | Message | Connection | Description |
|---|---|---|---|
| xx | Ext-Act-Ctrl | ? | |
| | | | |

#### Type xx: External Activity Control (Ext-Act-Ctrl) message

This message will be sent by AP or ST , to a channel that is on the same frequency or shifted by SHFT_FREQ (MHz). The message implies a roaming procedure, if the SHFT_FREQ # 0.

Table 1 – TLV for Ext-Act-Ctrl

| Name | Type | Length | Value |
|---|---|---|---|
| SHFT_FREQ | | 1 | Frequency shift of channel to be controlled |
| Control | | 2 | Use the OR function<br><br>0h80: Restraint downlink transmission, use IME_STEP_1<br>0h40: Restraint downlink transmission, use TIME_STEP_2<br>0h20: Restraint up-link transmission, use TIME_STEP_1<br>0h10: Restraint up-link transmission, use TIME_STEP_2<br>0h08: Increase downlink transmission, use TIME_STEP_1<br>0h04: Increase downlink transmission, use TIME_STEP_2<br>0h02: Increase up-link transmission, use TIME_STEP_1<br>0h01: Increase up-link transmission, use TIME_STEP_2 |

TIME_STEP_1 may be 2% of MAC Frame duration, TIME_STEP_2 may be 5% of the MAC Frame duration. The higher STEP_2 may be necessary when a user transmitting during "interference free" period has much data to transmit.

## *PHY signaling*

### Timing:

The signal will be send at the end of MAC FRAME. The signal duration will be 1 symbol time, when using OFDM256 FFT.

### Signaling

The principle of PHY signaling is to transmit energy (sub-carriers) in different spectrum zones.
In order to increase the resistance to collisions, and minimize the signaling duration, will be used an carrier OR system..
The channel width of the system to be controlled should be detected by the system that makes requests to that system.
The channel is spit into 64 sub-bands, numbered from 1 to 64. Table 2 shows channel splitting.
Table 3 shows the signaling bins allocation for every message. Table 4 shows the bin allocation for Frame SYNC_MARKERS.

Table 2– Bin allocation per sub-band

| Bin Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sub-band Number** | 10 | 14 | 18 | 22 | 26 | 30 | 34 | 38 | 42 | 46 | 50 | 54 |

Table 3 –PHY Message coding

| Message | Bin 1 | Bin 2 | Bin 3 | Bin 4 | Bin 5 | Bin 6 | Bin 7 | Bin 8 | Bin 9 | Bin 10 | Bin 11 | Bin 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Decrease DL | Decrease UL | Increase DL | Increase UL | STEP1 DL | STEP2 DL | STEP1 UL | STEP1 UL | DL Bin Check | | UL bin Check | |
| | | | | | | | | | D1 | D0 | D1 | D0 |
| Decrease downlink transmission, use TIME_STEP_1 | y | | | | y | | | | y | | | |
| Decrease downlink transmission, use TIME_STEP_2 | y | | | | | y | | | | y | | |
| Decrease up-link transmission, use TIME_STEP_1 | | y | | | | | y | | | | y | |
| Decrease up-link transmission, use TIME_STEP_2 | | y | | | | | | y | | | | y |
| Increase downlink transmission, use TIME_STEP_1 | | | y | | y | | | | y | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Increase downlink transmission, use TIME_STEP_2 | | | y | | | y | | | | y | | |
| Increase up-link transmission, use TIME_STEP_1 | | | | y | | | y | | | | | y |
| Increase up-link transmission, use TIME_STEP_2 | | | | y | | | | y | | | y | |

Table 4– Bin allocation per SYNC_MARKERS

| **Sub-band number** | 6 | 8 | 10 | 12 | 14 | 18 | 20 | 22 | 24 | 26 |
|---|---|---|---|---|---|---|---|---|---|---|
| **SYNC_MARKER Type 1** | y | | | y | y | | | | y | |
| | | y | | | y | y | | | | y |
| | y | | y | | | y | y | | | |
| **SYNC_MARKER Type 2** | | y | | y | | | y | y | | |
| | | | y | | y | | | y | y | |
| | | | | y | | y | | | y | y |
| **SYNC_MARKER Type 3** | y | | | | y | | y | | | y |
| | | y | y | | | y | | y | | |
| | | | y | y | | | y | | y | |

## Conclusion

A sharing proposal, to be used in License Exempt WirelessHUMAN, OFDM Mode is proposed; by applying the proposal, suitable for scheduled systems, will be possible to achieve a guaranteed level of QoS and to better use the spectrum. As the proposed PHY signaling is PHY independent, the method may suitable for all the 802.16 PHY modes.