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| 5 GHz ED Analysis |
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Abstract

This document analyzes the effect of using a −72 ED threshold in the presence of legacy devices using a −62 ED threshold in the 5 GHz band.

**Introduction**

An ED threshold of −72 dBm has been proposed in ETSI BRAN for 11be in the 5 GHz band. However, such a migration to −72 ED may not be without penalty. Spectral efficiency may be reduced, and when two or more legacy −62 ED devices interfere with a new −72 ED device, the new device may get caught in a capture effect that causes high latency and throughput degradation. This will be illustrated for a 3-BSS layout and a 2-BSS layout.

**3-BSS Layout**

The 3-BSS layout has the form of a prism, as shown in Figure 1 (more information is in the final section of this document).



Figure 1. 3-BSS prism layout

The prism layout has three APs at the top and three STAs at the bottom (three BSSs total).

Figure 2 shows a throughput comparison for a wanted signal of −54 dBm, with the AP interference varied between −78 and −60 dBm. The PD threshold is −82 dBm, and RTS/CTS is enabled. The left side shows the throughput when one AP uses −72 ED and the other APs use −62 ED. The right side shows the case where all APs use −62 ED.

One AP at -72 ED  All APs at -62 ED



all -62 ED

the node at -72 ED experiences degraded throughput

Figure 2. Throughput comparison (3-BSS)

A comparison of the access delay for the 3-BSS layout is shown in Figure 3.

One AP at -72 ED  All APs at -62 ED



the node at -72 ED has very high latency

all -62 ED

Figure 3. Access delay comparison (3-BSS)

The −72 AP may experience very long channel access delays and significant throughput degradation in this scenario. (The channel access delay in these plots is the maximum value between received BA or ACK frames measured over a 70 s simulation, and does not represent the average access delay or a CDF, which might not reveal occasional occurrences of very long access delays.)

The possible occurrence of 5 seconds or longer access delays indicates that the −72 AP periodically experiences a capture effect, during which each of the neighbour −62 APs transmit independently, while keeping the CCA busy at the −72 AP for possibly a long period of time.

The detrimental effect occurs between −75 and −62 dBm AP interference in this layout, and for wanted signal levels higher than −70 dBm (see results in the final section of this document). The typical OBSS interference in a non-managed environment is between −75 and −70 dBm, and wanted signal levels higher than −70 dBm may be common, so it may be likely that this situation can occur in practice.

A similar capture effect can occur in this layout when the transmitters are STAs, except that the STA contention window can become very high under certain interference conditions (1023 slots, 9.3 ms), which allows PD to become more active, in some cases increasing the throughput at the −72 STA. However, a STA can always choose to voluntarily lower its ED threshold in these conditions, but when −72 ED is mandatory, raising the ED threshold to −62 is not an option (results using STA parameters are shown in the final section this document).

Figure 4 shows the impact on the throughput at a uniform ED threshold, for −54 dBm wanted signal level.

All APs at −72 ED All APs at −62 ED



time sharing starts too soon at −72 ED

all -62 ED

all -72 ED

spatial reuse at −62 ED is more efficient in this case

Figure 4. Throughput comparison at uniform ED threshold (3-BSS)

This comparison shows that time sharing (−72 ED) will be less efficient than spatial reuse (−62 ED) for this level of wanted signal, in the 3-BSS prism layout. This will be the case for any wanted signal levels higher than −70 dBm (see results at in the final section of this document). When all devices use −72 ED, spatial reuse will turn into time sharing at about −75 dBm AP interference, but when all devices use −62 ED, this will only happen at about −65 dBm AP interference, when three links are active.

**2-BSS Layout**

Another example layout is shown in Figure 5, with two BSSs and three transmitting STAs, in which the location of BSS1 is varied relative to BSS2. The wanted signal levels are fixed at −56 dBm in BSS1 and −58 dBm in BSS2. STA1 and STA3 can cause a capture effect at STA2 when STA2 uses −72 ED.



Figure 5. 2-BSS layout

The throughput for BSS2 is shown in Figure 6.

STA2 at −72 ED  All STAs at −62 ED



STA2/STA3

(-62 ED)

the STA at -72 ED has lower throughput

STA3

(-62 ED)

STA2

(-72 ED)

Figure 6. Througput comparison (2-BSS)

The access delay for BSS2 is shown in Figure 7.

STA2 at −72 ED  All STAs at −62 ED



STA2 at -72 ED has very high latency

STA3

(-62 ED)

STA2/STA3

(-62 ED)

STA2

(-72 ED)

Figure 7. Access delay comparison (2-BSS)

STA2 can experience significant access delay and reduced throughput when using −72 ED, similar to the effects observed in the 3-BSS prism layout. The detrimental effect at STA2 occurs for AP interference levels between −79 and −73 dBm in this case.

A throughput comparison for all STAs at a uniform ED threshold of either −72 or −62 dBm is shown in Figure 8.

All STAs at −72 ED All STAs at −62 ED



all -62 ED

all -72 ED

STA2/STA3

STA1

STA2/STA3

STA1

spatial reuse at −62 ED is more efficient in this case

time sharing starts too soon at −72 ED

Figure 8. Throughput comparison at uniform ED threshold (2-BSS)

This comparison shows that time sharing at −72 ED will be less efficient than spatial reuse at −62 ED in this case, for AP interference levels above −79 dBm.

**Conclusions**

A device using −72 ED in the presence of −62 ED legacy devices may experience very high latency and considerable throughput degradation.

Time division at −72 ED can reduce the spectral efficiency relative to spatial reuse at −62 ED.

Therefore, a migration in the 5 GHz band toward −72 ED may not be without penalty.

A device can always voluntarily use −72 ED if that would result in higher throughput. But the opposite is not true, a device could never use −62 ED when −72 ED is mandatory.

With a trend toward multi-AP mesh networks, the odds for relatively high wanted signals and co-channel APs may increase. Being able to efficiently operate APs on the same channel will provide more flexibility in channel planning for such networks.

* **Simulation Settings 3-BSS Prism Layout**
	+ 3 APs in ceiling, 3 STAs on ground
	+ 802.11n channel model A
	+ 24 dBm Tx power
	+ 20 MHz channel width
	+ 4.6 – 5 ms TXOP (randomly selected per TXOP)
	+ Frame exchanges:
		- RTS/CTS/AMPDU/BA
		- Data/ACK
	+ Full buffer traffic, downlink or uplink
	+ Maximum PHY rate 346.7 Mbps (VHT MCS9, 20 MHz, 4ss, short GI)
	+ Wanted signals (prism height) in the range −87 dBm to −34 dBm, fixed per scenario
	+ AP interference levels (prism width) in the range −78 dBm and −60 dBm, sweep per scenario
* **Example Prism Layout**



* **Simulations**
	+ There are 3 groups of simulations:
		- APs as transmitters, with RTS/CTS/AMPDU/BA
		- STAs as transmitters, with RTS/CTS/AMPDU/BA
		- STAs as transmitters, with Data/ACK (no RTS/CTS)
	+ For each group, there are throughput and access delay plots:
		- left plot: one node uses −72 ED and the others use −62 ED
		- right plot: all nodes use −62 ED
		- the access delay represents the maximum time between two consecutively received BA or ACK frames
		- the wanted signal is fixed for each plot, the interference level is changed as a sweep

(APs Tx, with RTS/CTS)

One AP at −72 **Throughput** All APs at −62

















(APs Tx, with RTS/CTS)

One AP at −72 **Access Delay** All APs at −62

















(STAs Tx, with RTS/CTS)

One STA at −72 **Throughput**  All STAs at −62

















(STAs Tx, with RTS/CTS)

One STA at −72 **Access Delay** All STAs at −62

















(STAs Tx, Data/ACK)

One STA at −72 **Throughput**  All STAs at −62

















(STAs Tx, Data/ACK)

One STA at −72 **Access Delay**  All STAs at −62















