Impact of Frame Duration on Cross-Channel Interference and Coexistence in IEEE 802.11bn NPCA

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***Abstract*—Non-Primary Channel Access (NPCA), introduced in IEEE 802.11bn, enables stations to transmit on secondary channels when the primary is occupied, improving spectrum reuse in overlapping BSS (OBSS) environments. However, NPCA may cause cross-channel interference to other BSSs. In this paper, we investigate how NPCA frame duration influences channel utilization and throughout for other BSSs. Using a time-slotted simulation framework, we evaluate inter-BSS interactions under varying frame lengths. Our findings show that longer NPCA frames increase throughput but reduce fairness for other BSSs, while shorter frames lessen interference but limit throughput gains. These results highlight a trade-off between spectrum efficiency and coexistence fairness, offering insights for NPCA configuration in future Wi-Fi 8 systems.**

***Index Terms*—Non-Primary Channel Access, NPCA, IEEE 802.11bn, WLAN, Wi-Fi 8.**

I. Introduction

IEEE 802.11 supports bandwidths up to 320 MHz by aggregating 20 MHz channels. However, mandatory use of a primary channel for backward compatibility causes inefficiency when it is occupied by overlapping BSS (OBSS) traffic while secondary channels remain idle [1], [2].

To address this, IEEE 802.11bn introduces non-primary channel access (NPCA) [3], which allows a station to temporarily transmit on a secondary channel during primary-channel OBSS activity. Although NPCA enhances spatial reuse, it can also cause cross-channel interference, especially when adjacent BSSs rely on overlapping channels as their respective primaries. The severity of this interference depends on the duration of NPCA transmissions—long frames prolong blocking effects, while short frames reduce interference but may limit throughput.

This paper investigates the impact of NPCA frame duration on inter-BSS coexistence in terms of channel utilization and throughput of each stations (STAs).

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II. Non-Primary Channel Access

NPCA is a mechanism defined in IEEE 802.11bn to enhance spectral efficiency in OBSS environments. In traditional operations, each STA monitors and accesses only its designated primary 20 MHz channel. However, this constraint often leads to idle periods in secondary channels, even when they are available.

NPCA addresses this by allowing STAs to monitor the activity on their primary channel. When OBSS traffic is detected, the STA is permitted to switch to a secondary channel, called NPCA channel, to transmit. After completing the NPCA transmission, the STA returns to the primary channel and resumes normal contention.

Although NPCA improves reuse, it can cause interference when the secondary overlaps with another BSS's primary. This interference can block the other BSS's access and thus it may degrade fairness especially when the NPCA transmission duration is long. Understanding the impact of such interference is critical for coexistence-aware NPCA design.

III. Simulation Results

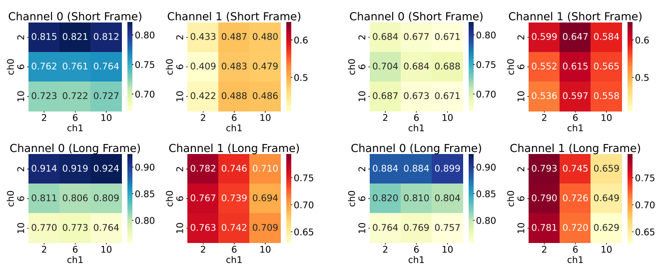
We evaluate how NPCA frame duration affects inter-BSS coexistence. Two overlapping BSSs are considered where one uses NPCA, which is primary transmission on Channel 1 and NPCA transmission on Channel 0, respectively. The other BSS is legacy-only on Channel 0, allowing us to observe potential interference from NPCA. STAs follow CSMA/CA with slot-based state updates, and NPCA STAs switch to the NPCA channel when OBSS activity is detected. Simulation parameters follow IEEE 802.11 standards and are summarized in Table I.

A. Channel Utilization

Channel utilization is defined as the valid channel occupation ratio. As shown in Fig. 1, when there are small STAs in Channel 0, enabling NPCA can noticeably reduce the utilization of NPCA channel, particularly with short Physical Protocol Data Unit (PPDU) frame duration. This reduction is attributed to NPCA-capable STAs in Channel 1 transmitting

TABLE I: Summary of Simulation Settings

Description	Value
Simulation time	500,000 μs
Slot duration	9 μs
Number of channels	2×20 MHz (Channels 0 and 1)
STAs per channel	2, 6, or 10 STAs
NPCA enabled channel	Channel 1 only
OBSS enabled channel	Channel 1 only
OBSS generation rate	0.05 per slot
OBSS frame size	Uniform in [20, 200] slots
Frame duration (Short)	33 slots (300 μs)
Frame duration (Long)	165 slots (1,500 μs)
NPCA activation condition	Primary OBSS + idle secondary channel
NPCA switching delay	5 slots
NPCA switching back delay	5 slots
Transmission protocol	CSMA/CA



(a) (b)

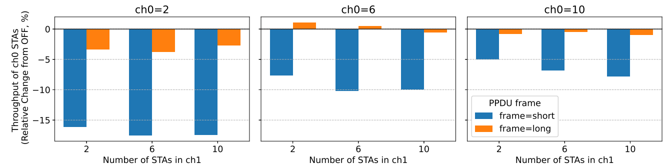
Fig. 1: Heatmap figures of channel utilization. **(a)** All STAs operate without NPCA and **(b)** STAs in Channel 1 are NPCA-enabled.

on Channel 0 during OBSS periods. While Channel 0 itself does not employ NPCA, these cross-channel transmissions increase contention and collision probability on Channel 0, thereby lowering its valid channel occupation ratio. The impact is more pronounced with short PPDU frame durations, where frequent NPCA attempts from Channel 1 can cause noticeable utilization loss in Channel 0. This suggests that an excessive number of NPCA-enabled STAs in Channel 1 can inadvertently degrade the primary channel utilization of neighboring BSSs.

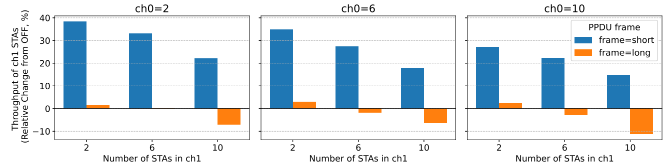
B. Per-STA Throughput

Fig. 2 illustrates the relative change in per-STA throughput when NPCA is enabled, compared to the NPCA-disabled baseline. Two key observations emerge. First, the number of STAs that operate NPCA on Channel 1 significantly influences performance. With short PPDU frames, enabling NPCA generally improves the throughput of Channel 1 STAs by allowing additional transmission opportunities during OBSS periods, albeit at the cost of reduced throughput for Channel 0 STAs due to increased contention.

Second, when the number of NPCA-enabled STAs in Channel 1 is large and the PPDU frame duration is long, enabling NPCA can actually degrade throughput in both channels. This degradation arises from prolonged channel occupation by long frames, which increases collision probability and



(a)



(b)

Fig. 2: Relative throughput changes when NPCA is enabled. **(a)** throughputs associated to BSS in Channel 0 and **(b)** throughputs associated to BSS in Channel 1, respectively.

reduces available transmission opportunities in the neighboring channel.

These results suggest that optimal NPCA deployment should account for both the number of NPCA-enabled STAs and the frame duration, as inappropriate configurations may lead to unintended performance loss.

IV. Conclusion and Future Works

This paper analyzed the impact of NPCA in IEEE 802.11bn on channel utilization and throughput under various STA distributions and PPDU frame durations. Simulation results showed that while NPCA can enhance spectral efficiency by exploiting transmission opportunities during OBSS periods, its benefits are highly dependent on network configuration. In particular, when a large number of STAs in the NPCA channel are enabled with short PPDU frames, NPCA may lead to increased contention and reduced throughput in NPCA channel. These findings highlight the need for careful tuning of NPCA-enabled STA numbers and frame duration settings to balance the gains and mitigate performance degradation.

For future work, we plan to investigate adaptive NPCA strategies that adjust PPDU frame duration based on the number of STAs and channel conditions. We also intend to explore machine learning methods to optimize NPCA in real time, ensuring fairness and throughput across diverse scenarios.

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