Exploring Low-Latency and High-Reliability Wi-Fi with Co-RTWT

Kamil Szczech
AGH University of Krakow
Krakow, Poland
kamil.szczech@agh.edu.pl

Szymon Szott
AGH University of Krakow
Krakow, Poland
szymon.szott@agh.edu.pl

***Abstract*—Emerging real-time applications in industrial and consumer wireless networks impose stringent requirements on latency and reliability. To address these demands, IEEE 802.11bn introduces the Coordinated Restricted Target Wake Time (Co-RTWT) mechanism, which reserves channel access intervals for priority traffic. Co-RTWT is an extension of the previously existing R-TWT mechanism to multi-access point coordination (a new Wi-Fi 8 feature), enabling synchronized transmission scheduling across multiple access points. As a new mechanism, Co-RTWT has not yet been thoroughly investigated. In this paper, we present the current state of knowledge regarding R-TWT and Co-RTWT and highlight existing gaps in our understanding. Furthermore, we outline the research questions that will guide future studies and the methodology we intend to employ.**

***Index Terms*—Co-RTWT, QoS, Wi-Fi 8, low-latency.**

I. INTRODUCTION

Emerging applications such as VR streaming, holographic communication, and automation in Industry 5.0 demand both ultra-low latency (as low as 10 ms) and high reliability from wireless networks [1], [2]. Although wired technologies such as Ethernet provide the required guarantees [3], [4], they are often impractical due to user comfort constraints or environmental conditions. The widespread use of IEEE 802.11 (Wi-Fi) networks makes them a natural candidate for such scenarios. However, their popularity has led to increased congestion, making it progressively more difficult to effectively support priority traffic.

To address these challenges, efforts are being made to enable deterministic Wi-Fi operation, along with improved coordination between access points (APs) through mechanisms such as multi-AP coordination (MAPC) [5]. MAPC refers to a set of methods that allow multiple neighboring APs to coordinate their transmissions, share scheduling information, and reduce interference, thereby improving overall network efficiency and reliability. Among these MAPC methods, Coordinated Restricted Target Wake Time (Co-RTWT) stands out as a prime candidate for supporting priority traffic, as it is purpose-built to reserve channel access intervals for priority transmissions, rather than merely reducing interference as a side effect. Co-RTWT, introduced in Wi-Fi 8 [5], is an extension of the original R-TWT mechanism of Wi-Fi 7. R-TWT defines cyclic Service Periods (SPs) within a given Wi-Fi network (called a Basic Service Set, BSS), during which channel access is reserved to minimize contention. The interval between subsequent SPs is described by the wake interval (WI). However, this protection is limited to a single BSS and does not prevent interference from neighboring networks. Co-RTWT addresses this limitation by enabling APs to exchange SP scheduling information across multiple BSSs, as illustrated in Figure 1, where two APs synchronize their SP schedules so that stations (STAs) from both BSSs refrain from transmitting during protected periods. Based on this information, STAs are required to complete their transmissions (TXOPs) prior to the start of any SP, regardless of whether it originates from their own or a neighboring BSS. By extending SP awareness beyond a single network, Co-RTWT effectively reduces inter-BSS interference and improves the determinism of channel access, which is critical for supporting latency-sensitive traffic.

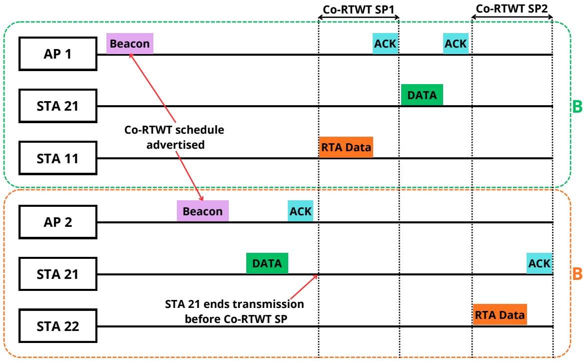

Fig. 1. Schematic diagram of a Co-RTWT system: priority data frames of real-time applications (RTA Data) are transmitted exclusively within protected Service Periods (SPs), whose schedule is synchronized and shared across multiple APs to reduce inter-BSS interference.

Our literature review (Section II) demonstrates the possibility of achieving high performance with the use of R-TWT but also highlights the lack of research on Co-RTWT in many fields. These gaps give rise to the highly interesting research questions listed in Section III. To answer these questions, we plan to employ a methodology that uses analytical models, simulations, and experiments. The research plans are summarized in Section IV.

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TABLE I
SELECTED SCIENTIFIC PUBLICATIONS ON TWT, R-TWT AND CO-RTWT MECHANISMS

Reference	Year	Methodology	Study Focus	Key Conclusions
[6]	2023	Experimental	Hardware validation of QTP in R-TWT	Legacy STAs non-compliant with R-TWT
[7]	2024	Experimental	Evaluation of Co-SR and R-TWT for low-latency traffic	R-TWT meets $<$ 10 ms latency at 99 percentile
[8]	2024	Analytical + Sim	Delay and packet loss modeling for R-TWT	Enables parameter optimization for QoS
[9]	2024	Analytical + Sim	Impact of R-TWT WI on low-priority STAs	The relationship between the R-TWT WI and non-RTA throughput is not monotonic
[10]	2025	Simulation	Performance across IoT, real-time and bulk traffic	Guarantees bounded latency; R-TWT performs better with UDP than with TCP.
[11]	2025	Analytical + Sim	Comparison of TWT vs R-TWT	R-TWT needed for strict latency; TWT sufficient otherwise
[12]	2025	Analytical + Sim	PONTE scheduling (R-TWT + OFDMA)	Meets 99.99% reliability; 100x faster than benchmarks
[13]	2025	Analytical + Sim	TSN-like scheduling using R-TWT, QTP	Ensures deterministic traffic with minimal performance loss
[14]	2026	Simulation	Distributed Co-RTWT enabling overlapping R-TWT periods	Doubles weighted throughput; reduces PER and latency

II. STATE OF THE ART

Research to date has focused primarily on R-TWT, while Co-RTWT remains largely unexplored. Table I summarizes existing publications that investigate the performance of both R-TWT and Co-RTWT.

Most studies of R-TWT performance rely on analytical models [8], [9], [11]–[13], often validated through simplified simulations. These works show that R-TWT can effectively provide low latency for RTA traffic and provide a framework for appropriately configuring its parameters. Also, they highlight potential risks associated with improper parameter selection, which can significantly degrade the performance of legacy traffic [9]. However, to the best of our knowledge, no analytical model has yet been extended to multi-AP scenarios, nor has a comprehensive framework been developed to evaluate Co-RTWT performance in such environments.

Other analytical models combine R-TWT with additional mechanisms: scheduling multiple STAs in separate SPs to enable efficient Orthogonal Frequency-Division Multiple Access (OFDMA) servicing and reduce collision probability [12], or integrating Quieting Time Periods (QTP) to achieve deterministic transmission [13]. These results suggest that there are further research directions in combining Co-RTWT with other well-established 802.11 mechanisms.

The effectiveness of R-TWT is further confirmed by tests conducted on physical hardware. The results show that, with R-TWT, priority traffic achieved latency below 10 ms at the 99th percentile [7]. These findings demonstrate that R-TWT meets the requirements of industrial processes.

A key limitation of analytical models is their assumption that all STAs behave strictly in accordance with the standard. However, real-world deployments reveal otherwise: the default QTP setting of Wi-Fi 7 may not effectively silence all legacy STAs, and multiple QTP instances within a single beacon interval are not supported [6]. Since legacy STAs do not always comply with the standard, analytical results may significantly diverge from real-world performance.

Not much research focuses directly on Co-RTWT. In fact, only a single study exists, which combines Co-RTWT with spatial reuse [14], enabling decentralized identification of RTA STAs that can transmit within the same SP without additional collisions, while minimizing inter-AP signaling. This single study highlights a clear research gap.

In summary, there is still little research dedicated to Co-RTWT, particularly in multi-AP scenarios, under real-world hardware conditions, and considering ML-based adaptation. The following sections address these open research areas.

III. RESEARCH QUESTIONS AND METHODOLOGY

Despite recent advancements in R-TWT and the emergence of Co-RTWT, several key challenges remain unresolved, particularly in the context of real-world deployments, multi-AP environments, and future standardization. The research questions are the following:

Q1) Can existing analytical models of R-TWT be extended to multi-AP scenarios, and if so, what are the theoretical bounds on latency and reliability achievable with Co-RTWT?

Q2) What is the relationship between Co-RTWT configuration and the resulting latency, reliability, and throughput in multi-BSS environments?

Q3) Can a machine learning (ML) algorithm dynamically optimize the Co-RTWT parameters to maintain Quality of Service (QoS) under non-stationary traffic and channel conditions?

Q4) What are the fundamental performance boundaries of Co-RTWT and how could a next generation mechanism overcome them?

These research questions will be addressed sequentially, as each builds upon the findings of the previous one. The analytical model (Q1) provides the theoretical baseline, which is then used to guide the optimization of the parameters (Q2). The insights from Q1 and Q2, particularly the understanding of system behavior under varying conditions, form the necessary foundation for designing an adaptive ML-based system (Q3). Finally, the limitations identified throughout Q1–Q3 inform potential directions for future development (Q4).

To address these questions, we employ a combination of analytical, simulation, and experimental methods. Each method offers a different trade-off between accuracy and implementation complexity, as discussed below.

Analytical methods are a widely used tool in the performance analysis of network systems due to low hardware requirements and ease of use. The models currently available in the literature focus on the analysis of R-TWT systems. To date, there is a lack of analytical tools for describing systems using Co-RTWT. However, it appears that extensions of the Markov chain-based models from [8], [9], [11] would allow the analysis of environments using AP coordination. Such models would enable the derivation of relationships between WI and key QoS metrics such as delay distributions and the throughput of non-RTA traffic outside SP periods. Unfortunately, due to the simplifications required when constructing mathematical models, the results may differ from reality when studying complex systems. Analytical models will be used primarily to address Q1, providing theoretical bounds that will later serve as a baseline for simulation and experimental validation.

Simulations offer greater accuracy than analytical models, but at the cost of higher implementation complexity and computing requirements. Although existing R-TWT studies rely on simple proprietary simulators [8], [9], [11]–[13], accurately modeling multi-BSS environments with physical station placement requires a full-featured simulator such as ns-3. We plan to extend the currently available ns-3 code to reflect the conditions present in Co-RTWT networks. Research scenarios will focus on evaluating delay distributions in dense multi-BSS environments, including the combination of Co-RTWT with Co-SR. Since only a basic TWT implementation is publicly available for ns-3 [10], it will be necessary to extend it with Co-RTWT support. Simulations will serve as the primary tool for Q2 and Q3, and will validate the analytical results of Q1.

Experiments provide the most accurate representation of real-world conditions among all considered methods, as they rely on physical hardware and actual wireless environments. Since commercial off-the-shelf devices do not allow arbitrary modification of IEEE 802.11 parameters, we plan to use openwifi [15] – an open-source SDR-based Wi-Fi implementation already validated in Co-SR and R-TWT studies [7]. The openwifi testbed will be used to confirm observations made through analytical and simulation methods in comparable scenarios, ensuring that conclusions hold under real-world conditions.

Regarding Q3, a reinforcement learning-based approach will be investigated, in which an agent dynamically selects SP and WI parameters based on user-defined QoS requirements. The agent will also handle scheduling of multiple SP windows, adapting to varying traffic conditions and channel states. Insights from Q1 and Q2 will provide the foundation for designing and evaluating this adaptive algorithm.

IV. SUMMARY AND RESEARCH PLAN

Since emerging network applications demand high reliability and low latency, research is essential to ensure reliable performance. The proposed research will be conducted in four stages, aligned with the research questions outlined above. First, an analytical model of Co-RTWT will be developed and validated, establishing theoretical performance bounds (Q1). Second, the model will guide a systematic evaluation of Co-RTWT configuration parameters through simulation and experiments (Q2). Third, the insights gained will support the design and evaluation of an ML-based adaptive algorithm for dynamic parameter optimization (Q3). Finally, the limitations identified throughout will motivate a discussion of potential enhancements for next-generation Co-RTWT mechanisms (Q4). The expected results include an analytical framework, a simulation environment, and experimental validation using the openwifi platform, collectively advancing the understanding of deterministic Wi-Fi operation.

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