Poster: *Accordion*: Toward a Limited Contention Protocol for Wi-Fi 6 Scheduling

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ABSTRACT

Target Wake Time (TWT) is a new scheduling capability in Wi-Fi 6 that can improve network performance by reducing contention and increasing energy efficiency. In this paper, we revisit the classic Adaptive Tree Walk Protocol (ATWP) and show its relevance to the TWT-based scheduling problem in Wi-Fi. Inspired by ATWP, we propose a new algorithm, *Accordion*, which dynamically switches between contention-based and collision-free channel access strategies using TWT. Preliminary simulations show that *Accordion* can significantly enhance Wi-Fi network performance in terms of average throughput and latency with varying network loads.

CCS CONCEPTS

• **Networks** → **Wireless local area networks**; **Network dynamics**; **Link-layer protocols**; *Network simulations.*

KEYWORDS

Wi-Fi; Target Wake Time; Scheduling; MAC

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1 INTRODUCTION

In this work, we focus on a powerful scheduling feature called Target Wake Time (TWT) that is part of the IEEE 802.11ax amendment (Wi-Fi 6). TWT enables Stations (STAs) in a Wi-Fi network to coordinate and schedule their communication with the Access Point (AP) while conserving energy during idle periods.

In addition to significantly increasing the energy efficiency of STAs [4, 5], TWT also alters the channel access behavior in Wi-Fi networks as it introduces the capability to reduce or even eliminate contention entirely among STAs through scheduling. This introduces a new paradigm for scheduling in Wi-Fi that was not available before since earlier versions of Wi-Fi have typically employed a Carrier-Sense Multiple Access with Collision Avoidance (CSMA-CA) mechanism at the core for channel access.

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We revisit the classic Adaptive Tree Walk Protocol (ATWP) [1, 2]. that adaptively balances between contention-based and collision-free scheduling approaches. The two scheduling approaches have interesting trade-offs and ATWP allows a dynamic shift in the network operation on a continuum between the two extreme strategies. In this paper, we argue for the relevance of an ATWP-inspired strategy for Wi-Fi 6 and propose *Accordion*, a threshold-based scheduling approach that dynamically switches access strategies using TWT based on the network load. With an early iteration of *Accordion*, we demonstrate significant improvements to the Wi-Fi network throughput and latency performance.

2 COLLISION-FREE VS. CONTENTION-BASED CHANNEL ACCESS

Collision-free channel access: In a collision-free channel access scheme, generally achieved through Time-Division Multiple Access (TDMA), the central node allocates a dedicated time slot to each individual STA. Each STA transmits data exclusively during its designated time slot. It has been shown that TDMA can achieve the maximum possible throughput in a network where all STAs always have data to transmit (high load) [6].

Contention-based channel access: On the other hand, in a contention-based channel access scheme, any STA that has data transmits in the next available time slot with backoff mechanisms to handle collisions. Contention-based schemes are well suited for low- and moderate-load networks [3] as they offer flexibility and better latency performance (compared to TDMA).

Adaptive Tree Walk Protocol (ATWP): ATWP was explored in [1] as a balance between collision-free and contention-based channel access. For a group of STAs contending for channel access in a time slot, the group will be partitioned into two smaller subgroups if a collision occurs. Then, each subgroup of STAs are allowed to contend for channel access only in their designated time slot. A given subgroup of STAs will be further partitioned into two smaller subgroups if another collision occurs. In a recursive manner, ATWP partitions a (sub)group of STAs into two smaller subgroups upon the occurrence of a collision till there is no further collision. Overall, ATWP behaves similar to collision-free channel access under a high load and behaves similar to contention-based channel access under a low to moderate load.

3 *ACCORDION*: REVISITING ATWP FOR WI-FI

We rely on TWT to develop *Accordion*, an adaptive scheduling solution inspired by ATWP. A TWT agreement is established between an AP and an STA through a negotiation phase where TWT parameters are agreed upon. After an agreement is reached, TWT STAs are expected to be active for their respective Service Periods (SPs) to transmit/receive frames to/from the AP. within a single SP, the AP can schedule multiple STAs that can contend and transmit.

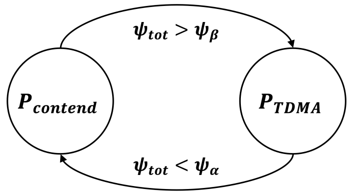


Figure 1: State diagram representation of *Accordion*

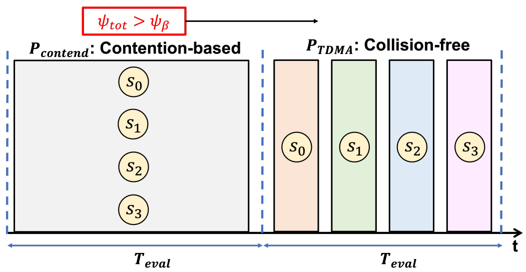
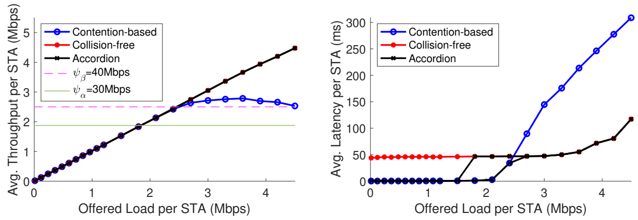


Figure 2: An illustration of *Accordion* as ψ_{tot} exceeds ψ_β with four STAs



(a) Average throughput per STA

(b) Average Latency per STA

Figure 3: Average throughput and latency performance of $P_{contend}$, P_{TDMA}, and *Accordion* for $N_{STA} = 16$ STAs

Accordion is designed for a Wi-Fi network with N_{STA} STAs that offer the same average uplink load at a given time without any downlink traffic. The AP periodically evaluates the total average throughput (ψ_{tot}) of the network over an evaluation period (T_{eval}). After every T_{eval}, the AP compares ψ_{tot} with appropriate lower and upper thresholds (ψ_α and ψ_β) and assigns one of the following two scheduling policies for the next T_{eval} as depicted in Fig. 1.

Contention-based policy $P_{contend}$: All STAs can contend for channel access in a single shared TWT SP over next T_{eval}.

Collision-free policy P_{TDMA}: Each STA is assigned a dedicated collision-free TWT SP of equal duration (T_{eval}/N_{STA}).

Fig. 2 depicts a case when a Wi-Fi network with four STAs $\{s_i\}_{i=0}^{3}$ currently following policy $P_{contend}$ has $\psi_{tot} > \psi_\beta$ in a given T_{eval}. Consequently, the policy is changed to P_{TDMA} for the next T_{eval} and will continue to follow P_{TDMA} until $\psi_{tot} < \psi_\alpha$. We set lower and upper thresholds ψ_α and ψ_β with $\psi_\beta > \psi_\alpha$ to avoid frequent oscillations between the two policies (a hysteresis behavior).

While ATWP is designed for a rigid time-slotted network, *Accordion* allows for dynamic timeslot durations that can be used to enforce fairness and prioritization. To demonstrate *Accordion*, we utilize simulations in ns-3 with a Wi-Fi network consisting of $N_{STA} = 16$ STAs connected to a single AP over the 2.4 GHz band through a 20 MHz channel. All STAs offer only uplink UDP traffic with the same average packet arrival rate at any instant.

Algorithm 1: *Accordion*: Adaptive Scheduling Policy

Input: N_{STA}, ψ_α, ψ_β, T_{eval}

$P_{current} \leftarrow P_{contend}$
while *true* **do**
  Measure ψ_{tot} over T_{eval}
  if $\psi_{tot} > \psi_\beta$ *and* $P_{current} == P_{contend}$ **then**
    $P_{current} = P_{TDMA}$
  if $\psi_{tot} < \psi_\alpha$ *and* $P_{current} == P_{TDMA}$ **then**
    $P_{current} = P_{contend}$

Through simulations (Fig. 3), we evaluate the effect of the offered load on average throughput and latency for the contention-based policy, collision-free policy, and proposed *Accordion* algorithm. We observe the trade-offs outlined in Section 2. For instance, as the offered load per STA exceeds 2.5 Mbps, the collision-free network outperforms the contention-based network in terms of latency.

With *Accordion* ($\psi_\alpha = 30\,Mbps$ and $\psi_\beta = 40\,Mbps$), we observe that the throughput achieved is over 75% better and the latency performance is over 60% better at a high offered load (4.5 Mbps per STA) compared to the contention-based network. We also observe the improvement in latency performance in comparison to the collision-free network where *Accordion* performs over 99% better at low offered loads. The choice of thresholds and metrics affects the overall performance of the network. Consider a network in which the offered load cyclically linearly increases from 0 Mbps to 72 Mbps and then decreases back to 0 Mbps. For instance, we observe that the thresholds of $\psi_\alpha = 40\,Mbps$ and $\psi_\beta = 50\,Mbps$ favoring $P_{contend}$ and the thresholds of $\psi_\alpha = 20\,Mbps$ and $\psi_\beta = 30\,Mbps$ favoring P_{TDMA} lead to an increase in latency by 8% and 14%, respectively.

4 CONCLUSION

In this paper, we briefly review ATWP and consider a scheduling problem with TWT in a Wi-Fi 6 (IEEE 802.11ax) network. Inspired by ATWP, we propose *Accordion*, a novel TWT scheduling approach that dynamically switches between collision-free and contention-based channel access with a throughput-based threshold. Preliminary simulation results show that the proposed *Accordion* algorithm significantly improves overall performance in terms of average throughput and latency in a TWT-featured Wi-Fi network.

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REFERENCES

[1] John Capetanakis. 1979. Generalized TDMA: The multi-accessing tree protocol. *IEEE Transactions on Communications* 27, 10 (1979), 1476–1484.

[2] John Capetanakis. 1979. Tree algorithms for packet broadcast channels. *IEEE transactions on information theory* 25, 5 (1979), 505–515.

[3] Bikramjit Singh, Olav Tirkkonen, Zexian Li, and Mikko A. Uusitalo. 2018. Contention-Based Access for Ultra-Reliable Low Latency Uplink Transmissions. *IEEE Wireless Communications Letters* 7, 2 (2018), 182–185.

[4] Changmok Yang, Jinmyeong Lee, and Saewoong Bahk. 2021. Target Wake Time Scheduling Strategies for Uplink Transmission in IEEE 802.11ax Networks. In *2021 IEEE Wireless Communications and Networking Conference (WCNC)*. 1–6.

[5] Hang Yang, Der-Jiunn Deng, and Kwang-Cheng Chen. 2018. On energy saving in IEEE 802.11 ax. *IEEE Access* 6 (2018), 47546–47556.

[6] Zhuo Yang, Yu-Dong Yao, Xiaochen Li, and Di Zheng. 2010. A TDMA-based MAC protocol with cooperative diversity. *IEEE Communications Letters* 14, 6 (2010), 542–544.