Impact of MU EDCA channel access on IEEE 802.11ax WLANs

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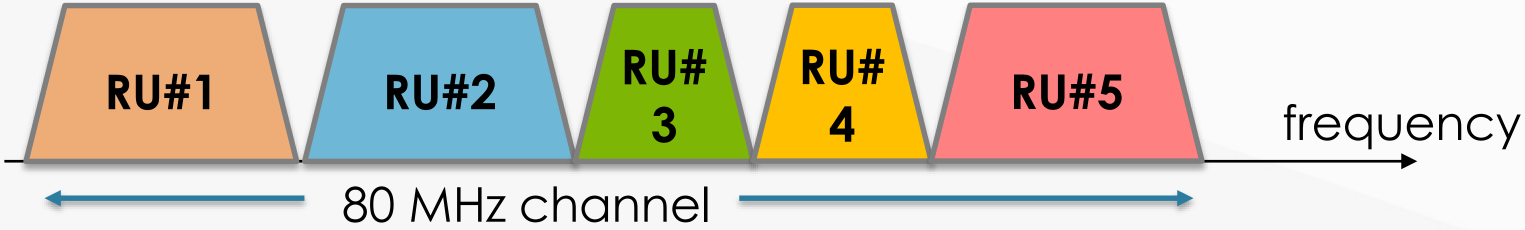
VTC 2019-Fall September 24, 2019

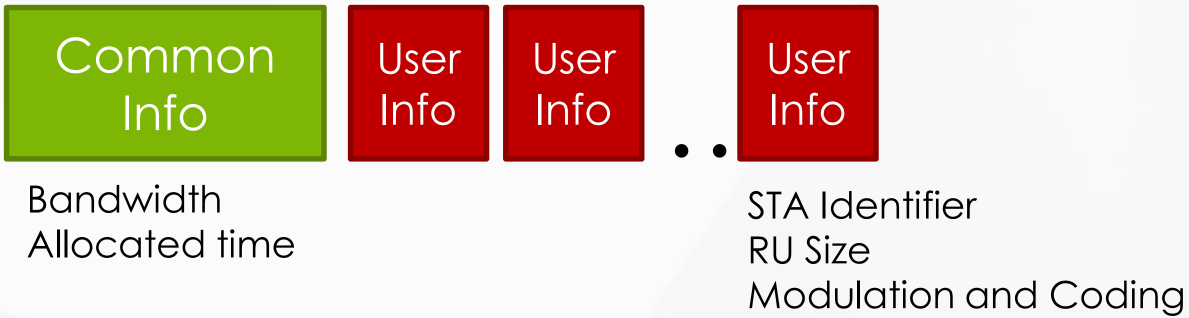
OFDMA for Dense WLANs

- Historically, 802.11 channel access has been CSMA/CA contention-based
  - Contention parameters (EDCA) advertised by Access Point (AP) in Beacons
  - Well-suited for small deployments but suffers from collision as network densifies
- 802.11ax introduced Orthogonal Frequency Division Multiple Access (OFDMA) to meet dense WLAN demands and minimize contention
- Channel of transmitting a frame is divided into sub-channels for transmissions to/from multiple number of STAs (end user devices)
  - Sub-channels are called resource units (RUs)
  - Each RU dedicated to a different STA and has its own PHY parameters

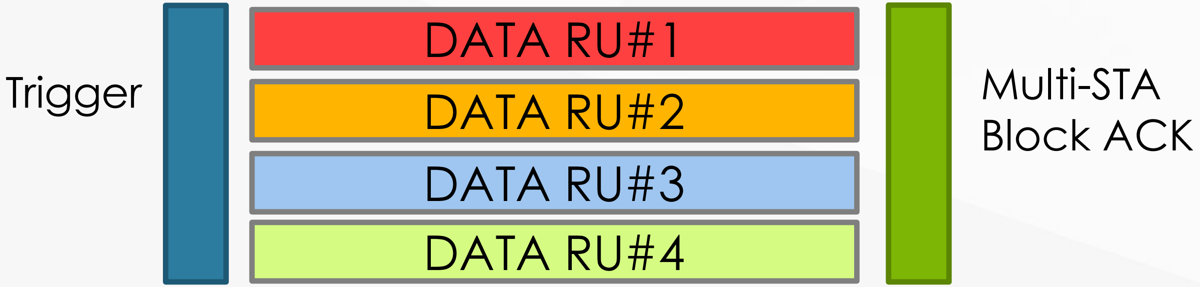


Uplink Multi-User Access

- Uplink OFDMA (UL MU) initiated by the AP via Trigger frame



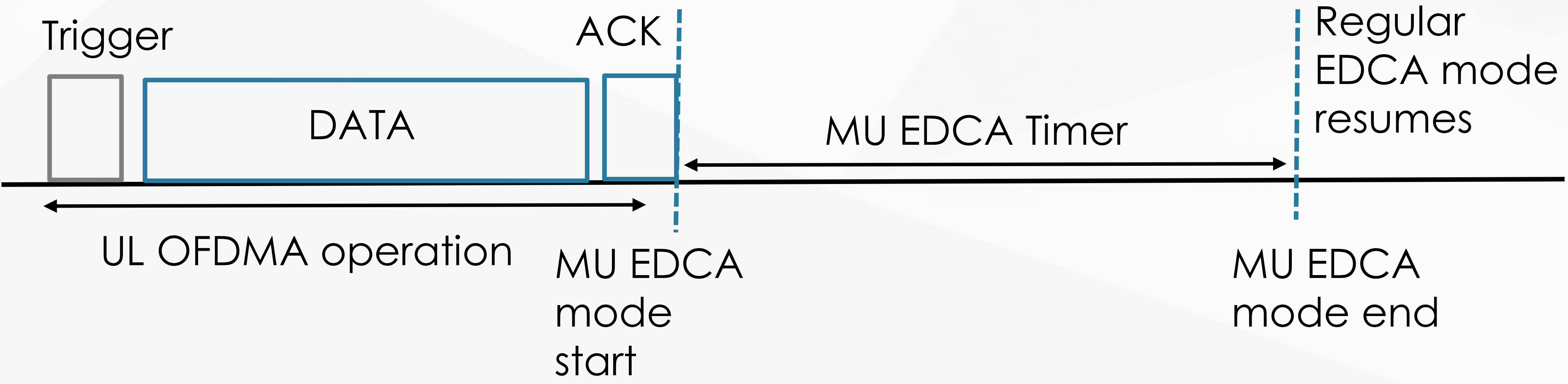
- For Trigger transmission, AP contends on the wireless medium
  - Trigger frame enqueued in one of the access queues



Multi-User EDCA (MU EDCA)

- Allowing STAs that utilized OFDMA RU grants to further contend using the regular EDCA would be detrimental to objective of reducing contention

- MU EDCA for temporary deprioritized access after RU grant
  - RU-granted STAs use MU EDCA parameters during MU EDCA Timer countdown
  - EDCA-based access may be **fully disabled** for a specific parameter set



Motivation

- MU EDCA period too small
    - o Falls back to regular EDCA –based network operation
    - o Radio utilization will fail to scale for dense WLANs

- MU EDCA period too high (~ 2 seconds)
    - o Performance degradation for real-time "worst-case latency" applications
    - o STA cannot perform operation mode switch e.g. power save, coexistence

- Participation in UL OFDMA
    - o STAs can dynamically change their participation in UL OFDMA
    - o Poor scheduling can lead to STAs disabling UL OFDMA operation

- **Analyzing the impact of MU EDCA on 802.11ax WLANs is much-needed for future 802.11ax deployments and next-generation standards development**

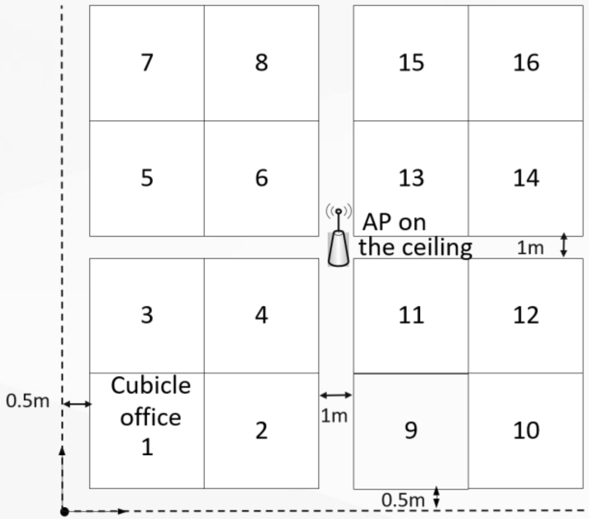
Contributions

Using custom ns-3 simulator with 802.11ax OFDMA functionality,

- **Throughput and latency gain analysis for 802.11ax OFDMA**
    - o Up to 4x throughput gain and consistent latency improvements over legacy EDCA
- **MU EDCA impact on dense WLAN performance**
    - o Temporary switch to MU EDCA-based access is indeed beneficial
- **Scalability of 802.11ax OFDMA operation**
    - o For a given latency bound, how density scales for trigger-based access?

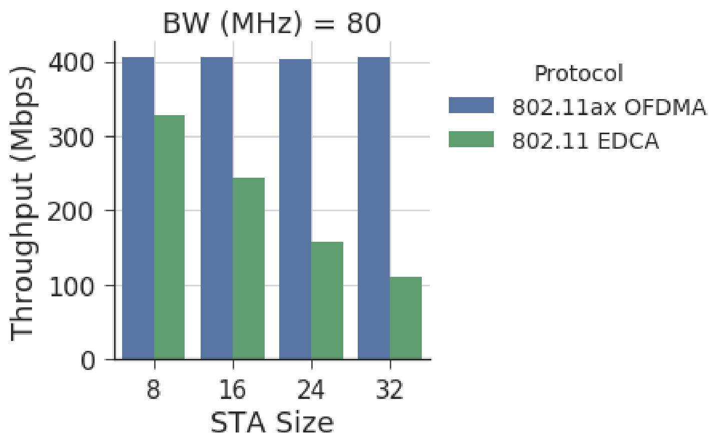
Network Model

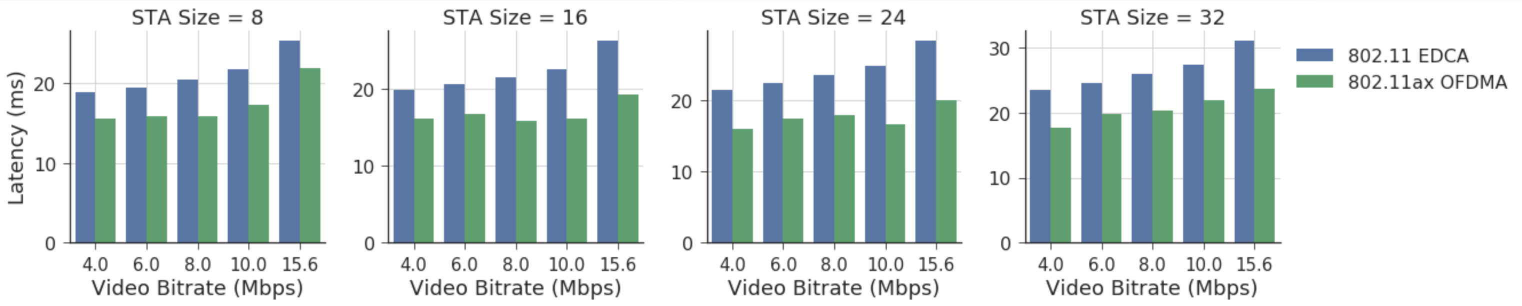
- **Enterprise office deployment scenario [1]**
  - Enterprise topology model and propagation loss model
  - Buffered video streaming for latency analysis [2]
- **Single AP** operating on 80 MHz channel in 5 GHz band
  - HE MCS 9 (~= 480 Mbps PHY rate) unless stated otherwise
- **OFDMA scheduling**
  - Round-robin manner with fixed groups of 4 STAs
  - Random RU allocation within the group
  - Queue size provided by STAs in QoS Control
    - Used for allocating the uplink transmit time
- Trigger enqueued in **EDCA Voice** for high priority
- EDCA **fully disabled** during MU EDCA countdown



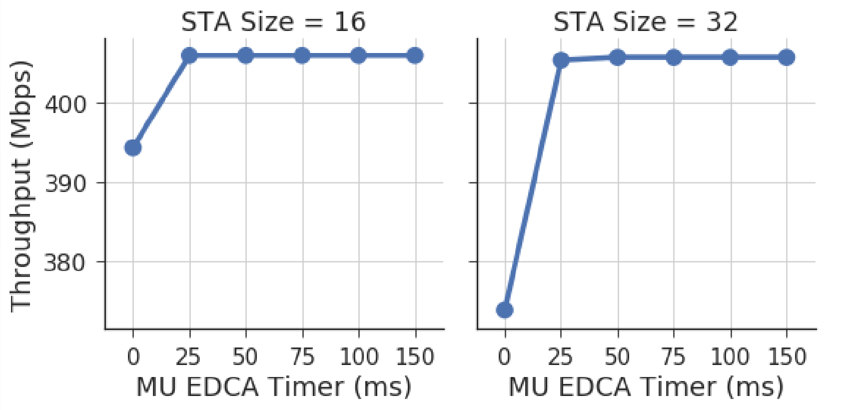
OFDMA MAC gain

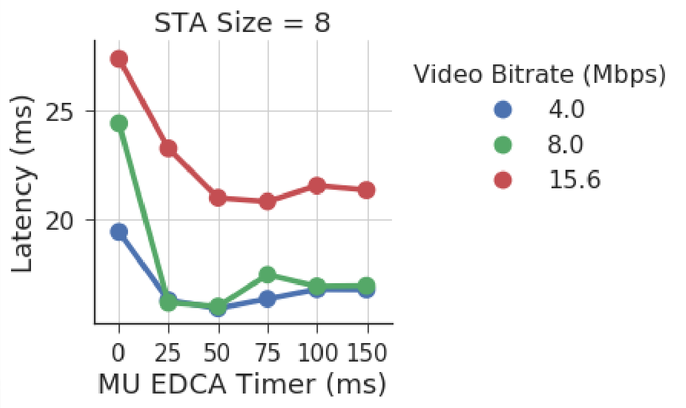
- Scheduled Access shows higher network throughput
  - EDCA suffers from collisions with increased congestion
  - Even without UL OFDMA power benefit, UL OFDMA provides up to 4x gain
- Simple round-robin mechanism provides consistent improvement in latency





MU EDCA Impact on dense WLAN performance

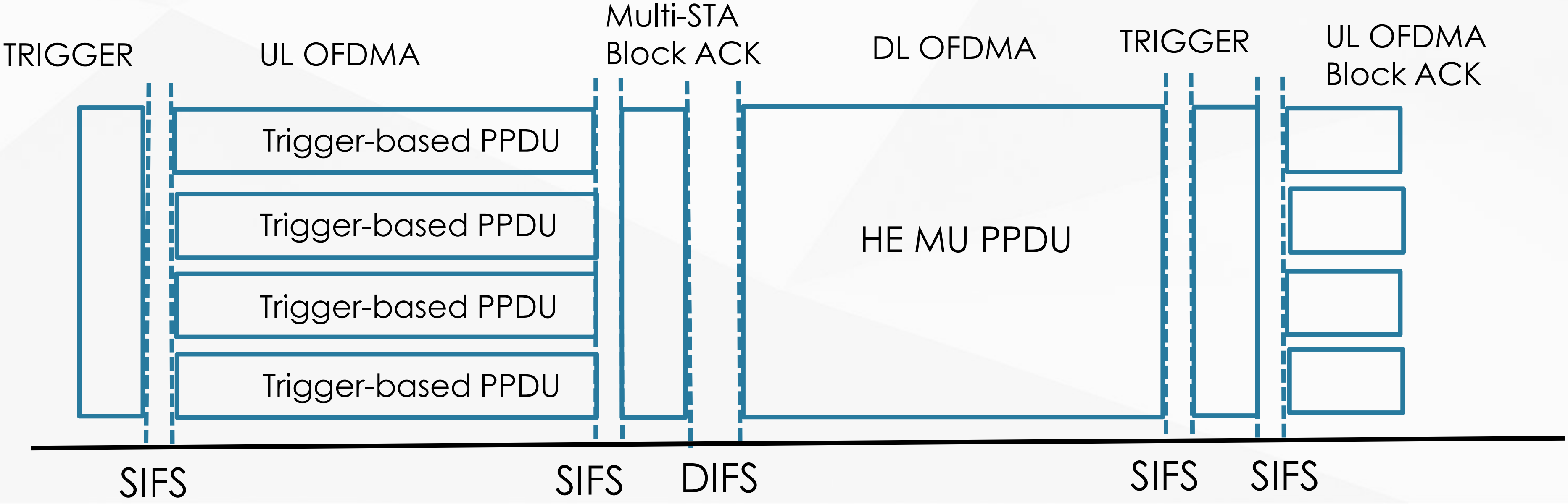




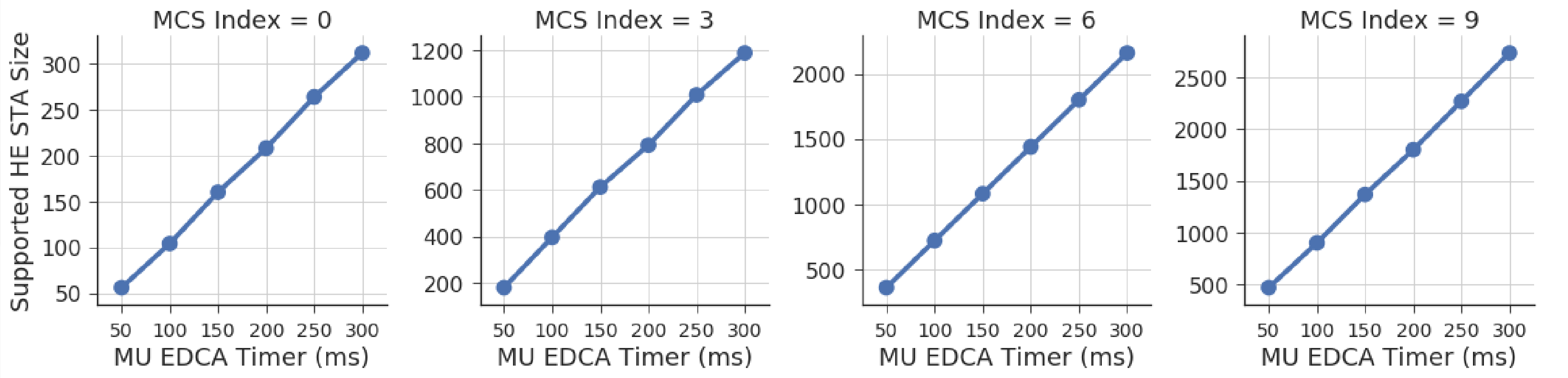
- MU EDCA Timer of 0 corresponds to not using MU EDCA
  - STAs switch to regular EDCA right after OFDMA RU grant
- Temporary switch to MU EDCA-based access is indeed beneficial
- MU EDCA Timer duration
  - With network size of 32 or less, contention impact not significant beyond 25 ms
  - Round-robin algorithm schedules STA before MU EDCA Timer expiry

OFDMA WLAN Scalability

- In an ideal OFDMA WLAN with fair scheduling, STAs are granted RUs without falling back to legacy EDCA
  - Before the MU EDCA Timer countdown expires
- For a given MU EDCA Timer, there is an upper bound on the network size



OFDMA WLAN Scalability



- MCS index = modulation and coding index for 802.11ax rates
- Assuming 1 DL and 1 UL 1500B packet per STA
- With a fair scheduling, AP can serve more than 100 active STAs at the lowest MCS with MU EDCA Timer of 100 ms

Related Works

- Fairness between UL OFDMA STAs and legacy STAs [3]
  - AP using high priority parameters for Trigger can starve legacy STAs
  - Model for AP selecting Trigger frame transmission contention parameters
- Scheduling algorithms for throughput and fairness trade-off [4]
  - AP utilizes buffer status reports to perform efficient scheduling
- Benefit of multi-user RTS/CTS for protecting multi-user transmissions [5]
  - Trade-off between overhead and collision avoidance
- **The related works are complementary to our contributions**

Conclusion and Future Work

- **Multi-User EDCA**
  - Beneficial for throughput and latency performance
  - Network scalable to hundreds of STAs

- **Further Consideration**
  - Multi-user EDCA protocol design for greenfield spectrum

- **Multi-channel/band and multi-AP transmissions in next-gen 802.11be**
  - Several new scenarios at the device scale and network scale
  - OFDMA expected to be a key fixture

References

[1] IEEE 802.11ax Task Group, "TGax Simulation Scenarios"

[2] 802.11ax Task Group, "11ax Evaluation Methodology"

[3] Khorov et al., "Several EDCA Parameter Sets for Improving Channel Access in IEEE 802.11ax networks," in *Proc. Of IEEE ISWCS*, 2016

[4] Bankov et al., "OFDMA Uplink Scheduling in IEEE 802.11ax Networks," in *Proc. of IEEE ICC*, 2018

[5] Bellalta et al., "AP-initiated multi-user transmissions in IEEE 802.11ax WLANs," *Elsevier Ad Hoc Networks*, vol. 85, 2019.