Improving VHT MU-MIMO Communications by Concatenating Long Data Streams in Consecutive Groups

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M.Eng. Presentation

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Roadmap

- Comparison between 802.11n and 802.11ac
- Overview of VHT MU-MIMO communication technologies
- VHT MU-MIMO communication
- Concatenating long data streams into groups
- Simulation results
- Conclusion and future work
- References

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Comparison of 802.11n and 802.11ac Standards

802.11n		802.11ac
4 spatial steams	→	Upgraded to 8 spatial streams
2.4 GHz and 5 GHz	→	5 GHz only
Modulation rate 64 QAM at coding rate of 5/6	→	Modulation rate of 256 QAM at coding rate of 5/6
20 MHz and 40 MHz	→	20 MHz, 40 MHz, 80 MHz, and 160 MHz
Block Convolutional Coder (BCC)	→	BCC and Low Density Parity Check (LDPC)
Transmit Beamforming (Optional)	→	Explicit NDP based Beamforming
A-MSDU and A-MPDU Frame Aggregation	→	A-MPDU only

Comparison of 802.11n and 802.11ac Standards (contd.)

High Throughput (HT) Communication Mode:

- Transmission of maximum 4 data streams to a single STA

Maximum data rate: 600 Mbps

Very High Throughput (VHT) Communication Mode:

- Transmission of maximum 8 data streams to a single STA

VHT Multi-User Multiple Input Multiple Output (MU-MIMO) Communication Mode:

- Transmission to 4 STAs simultaneously with maximum 4 data streams per STA

Maximum data rate: 6.77 Gbps

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Frame Aggregation and Block Acknowledgement

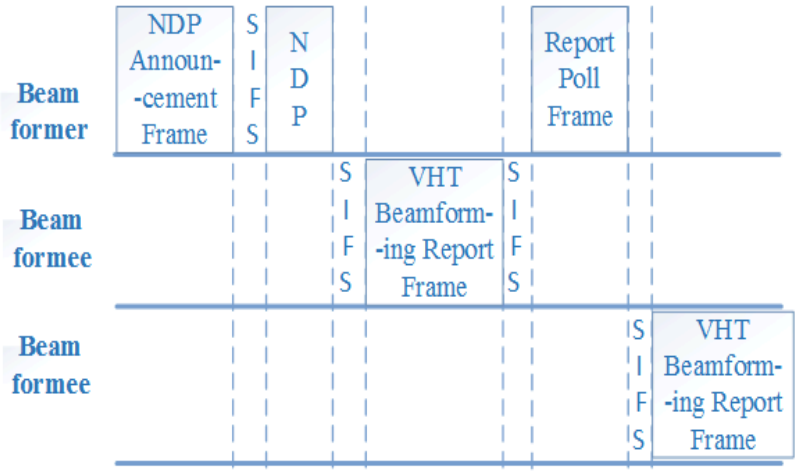
- Previous standards: one frame transmitted at a time over the channel
- Ineffective ratio of channel overhead and data payload
- Frame aggregation suggests transmission of multiple frames of payload along with one time overhead
- Frame aggregation (two levels):
  - Aggregated Multi Service Data Unit (A-MSDU)
  - Aggregated Multi-Protocol Data Unit (A-MPDU)
- 802.11ac only uses A-MPDU
- Block Acknowledgement: acknowledges all frames successfully received inside an A-MPDU

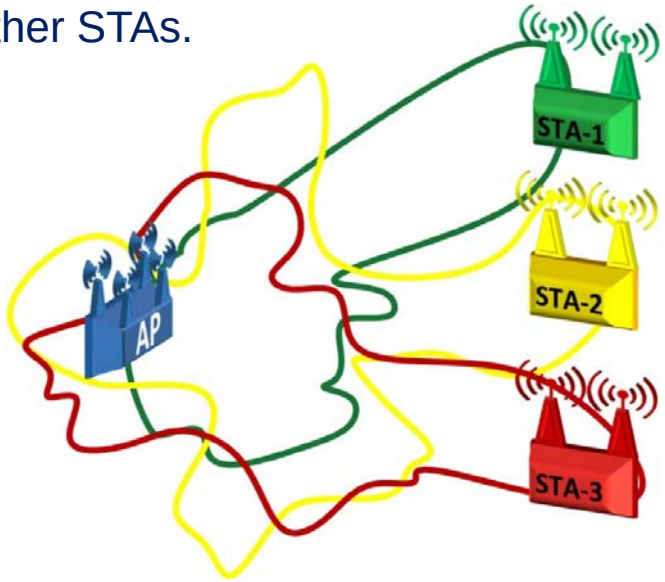
Table 1. 802.11ac A-MPDU Size

Serial No.	A-MPDU size (octets)
1	8,191
2	16,383
3	32,767
4	65,535
5	131,071
6	262,147
7	524,287
8	1,048,575

VHT Sounding Protocol

- Explicit beamfroming mechanism: a beamformer sends a Null Data Packet (NDP) to a beamformee.
- The beamformee receives the NDP, creates a steering feedback, and sends it to a beamformer. Used by beamformer to prepare steering matrix.
- The matrix provides steering of space-time streams in a direction of the recipient STA and nullifies the propagation to be received by other STAs.



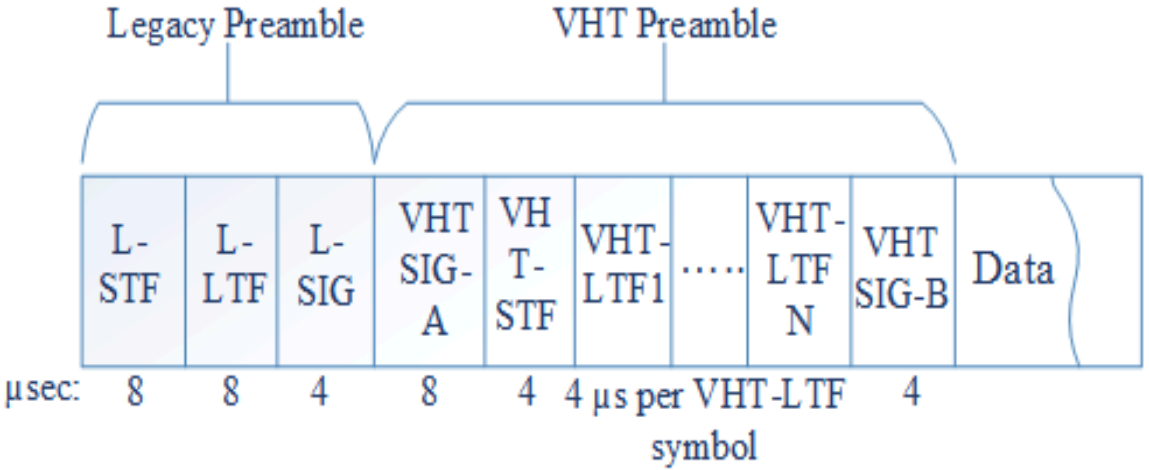


Group ID Assignment

- Access Point assigns a Group ID and a User Position ID to STAs.
- Group ID: assigned to up to four STAs. Each STA has a different User Position ID.
- An STA may be assigned multiple Group IDs. However, within the group, the User Position IDs are unique.
- Assignments of Group IDs are communicated to STAs via the “Group ID management frame”.

Very High Throughput (VHT) Preamble

- A new preamble is transmitted after a Legacy Preamble.
- Enhanced specifically to accommodate simultaneous multi-user transmissions over the same channel.
- VHT Preamble has two signaling fields: VHT SIG-A and VHT SIG-B.
- VHT SIG-A carries the collective information required by STAs of a group.
- VHT SIG-Bs are propagated in the direction of STAs.



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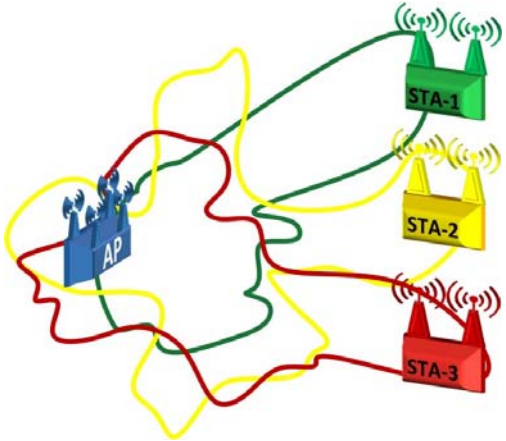
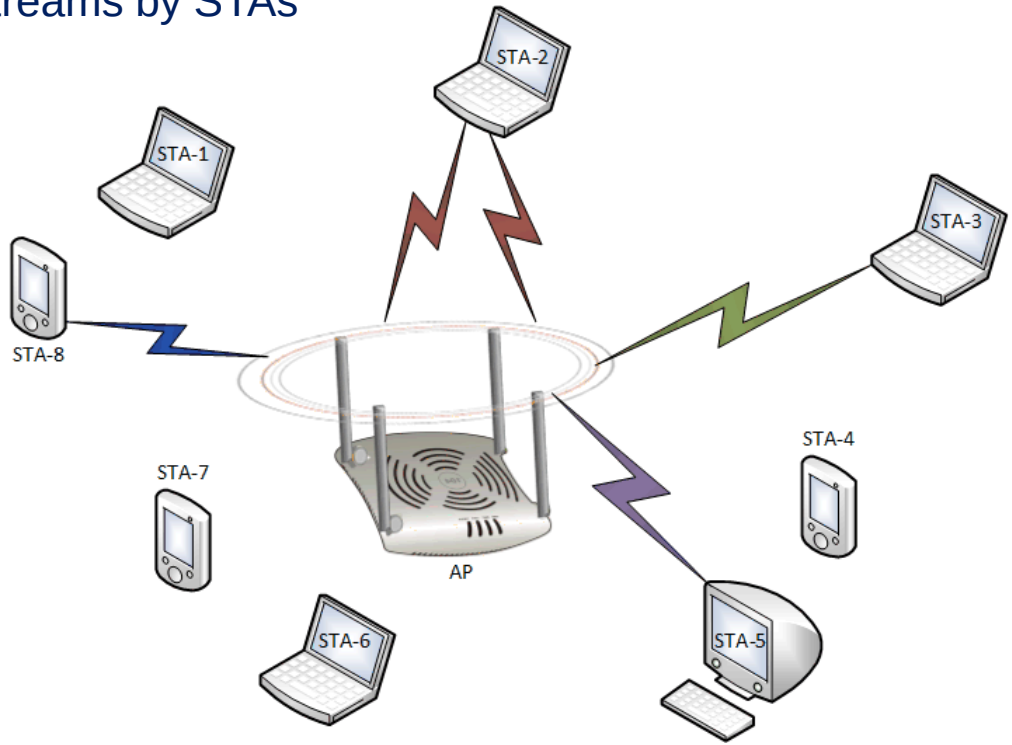
VHT MU-MIMO Communication

- AP in a downlink simultaneously transmits multiple streams of data to multiple STAs over the same channel width.
- The successful extraction of their own streams by STAs is the result of beamforming.
- Space-time streams of a particular STA are directed toward the STA while streams of other STAs are nullified in its direction.

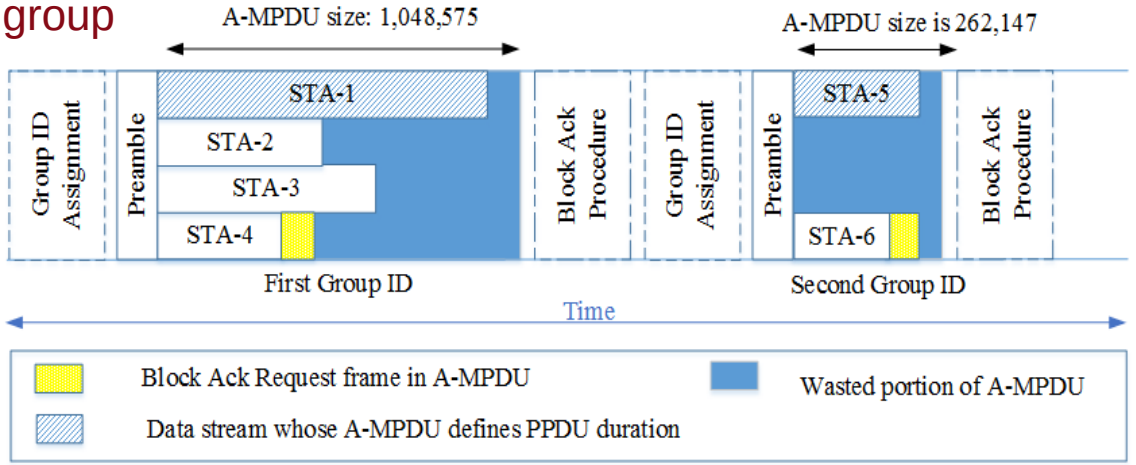




VHT MU-MIMO Communication: Example

VHT MU-MIMO Communication process of six STAs:

- Assumption: All STAs communicate with the same MCS index
- AP has collected steering feedback of all STAs using the VHT sounding process
- Selects STAs for first group
- Selects A-MPDU sizes for every STA MPDU
- Calculates PPDU duration of every space-time stream
- Decides PPDU duration of the group (the largest A-MPDU size)



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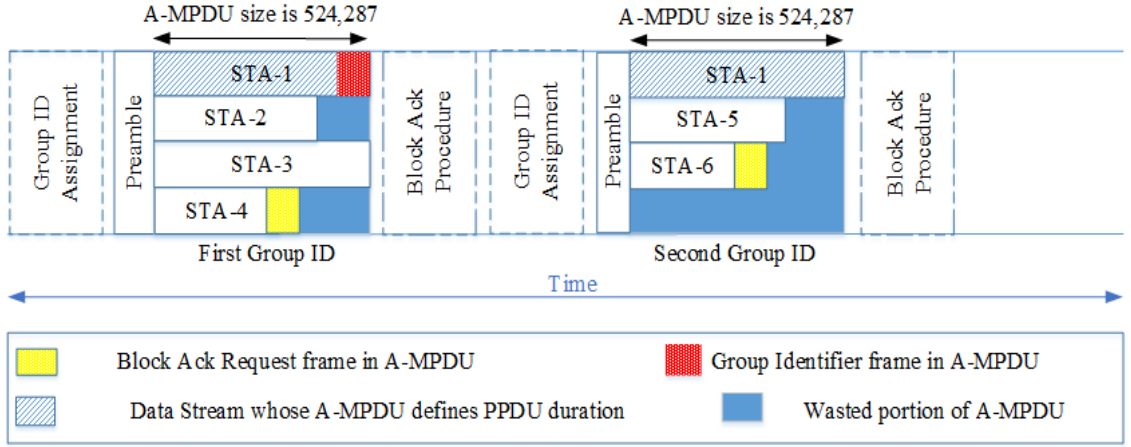
Concatenating Long Data Streams into Groups

Selection of the PPDU duration:

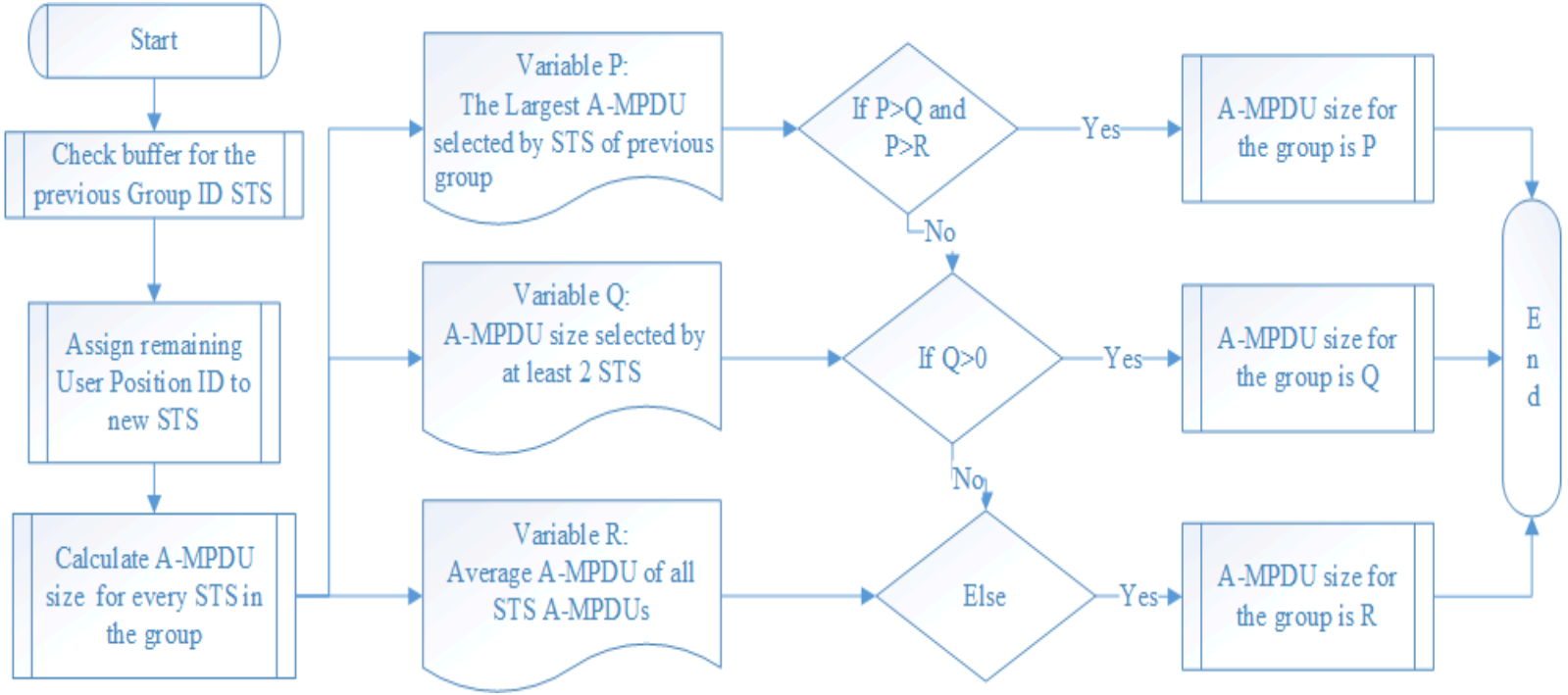
- Calculate the average of selected A-MPDUs of data streams and select the A-MPDU size that fits the calculated average.
- Reduce the size of the long data streams to the selected A-MPDU size and append a Group ID assignment frame.
- Calculate PPDU duration of the group based on the average A-MPDU.
- Transmit the remaining part of a long data streams in the next Group ID.



Concatenating Long Data Streams into Groups (cont.)

In two cases, the average of A-MPDUs is not selected as the A-MPDU size for the group:

- data stream in the first group is part of previous group
- two data streams select similar A-MPDU size



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Simulation Results: Transmission Time

- Generate 100 data streams of random sizes ranging between 2,000 and 1,048,575 octets.
- Calculate transmission time:

$$TXTIME = T_{LSIG\_PR} + T_{L-SIG} + T_{VHT-SIG-A} + T_{VHT-PR} + T_{VHT-SIGB} + T_{SYML} \times N_{SYM}$$

The preambles value:

$$T_{LSIG\_PR} + T_{L-SIG} + T_{VHT-SIG-A} + T_{VHT-PR} + T_{VHT-SIGB} = 40\ \mu s$$

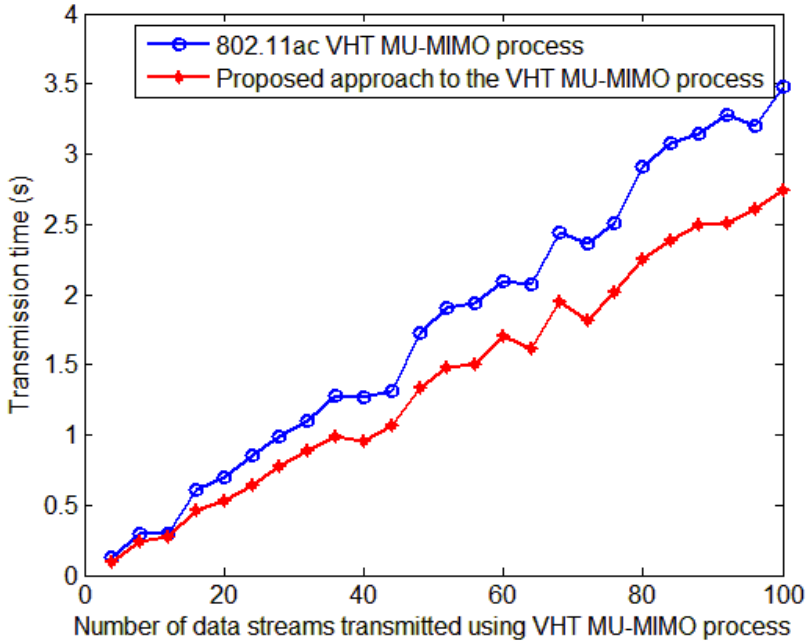
The NSYM of the data A-MPDU:

$$N_{SYM} = m_{STBC} \times \lceil (8 \times APEP\_LENGTH + N_{service} + N_{tail} \times N_{ES}) / (m_{STBC} \times N_{DBPS}) \rceil$$

- TSYML = 4, mSTBC = 1, Nservice = 16, Ntail = 8, NES=1, NDBPS= 104, and APEP_LENGTH = A-MPDU size is selected from Table 1 for STAs within a group.

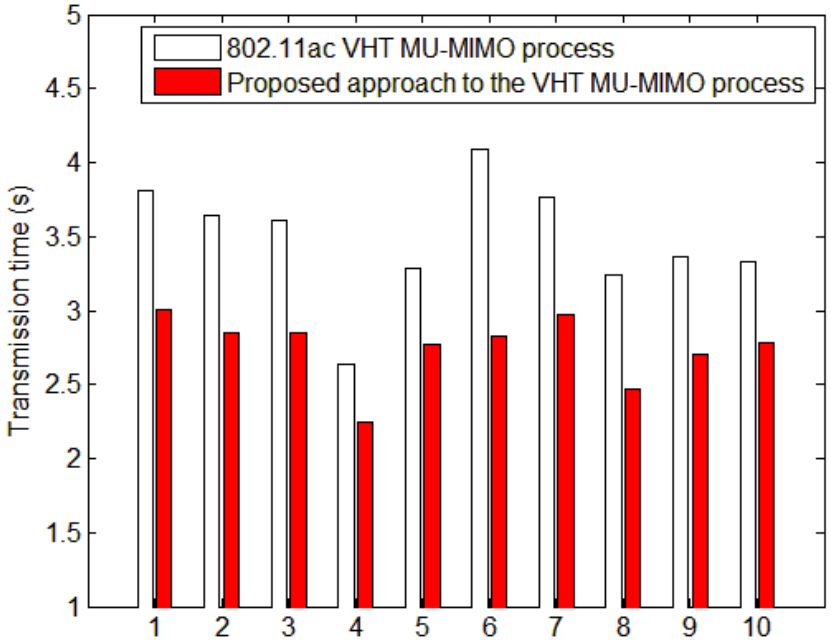
Simulation Results: Transmission Time

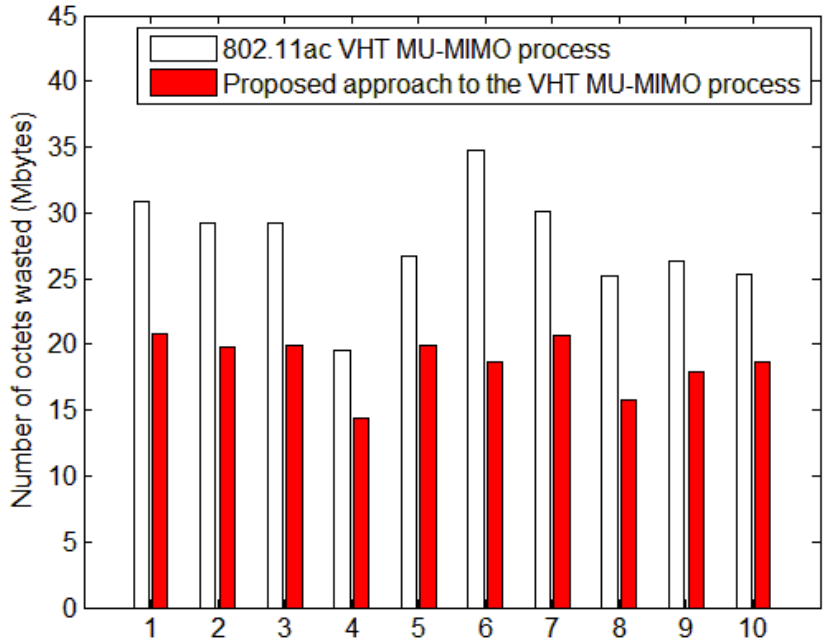
- We compare results of the standard VHT MU-MIMO communication process and the proposed approach.



Simulation Results: Transmission Time and Wasted Octets

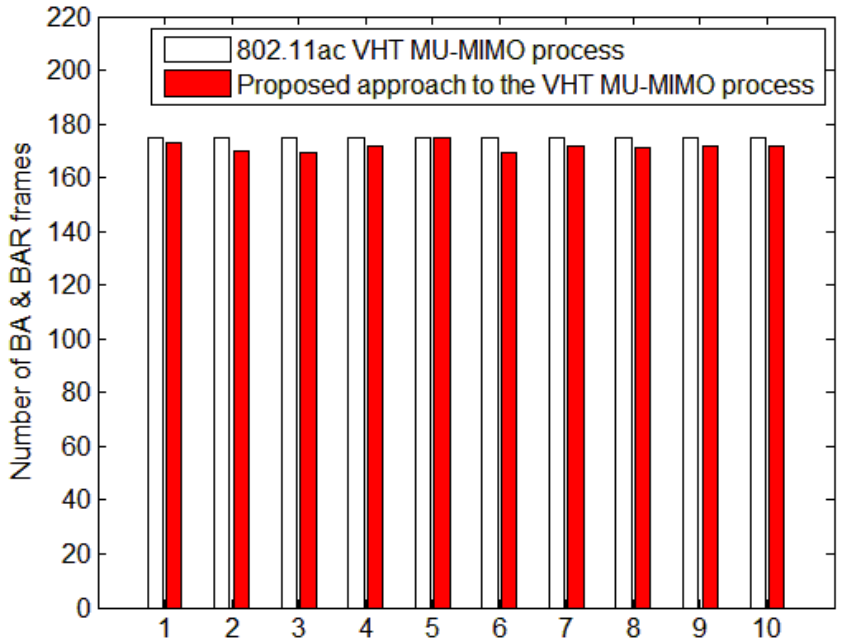
- Ten iterations with hundred random data streams:

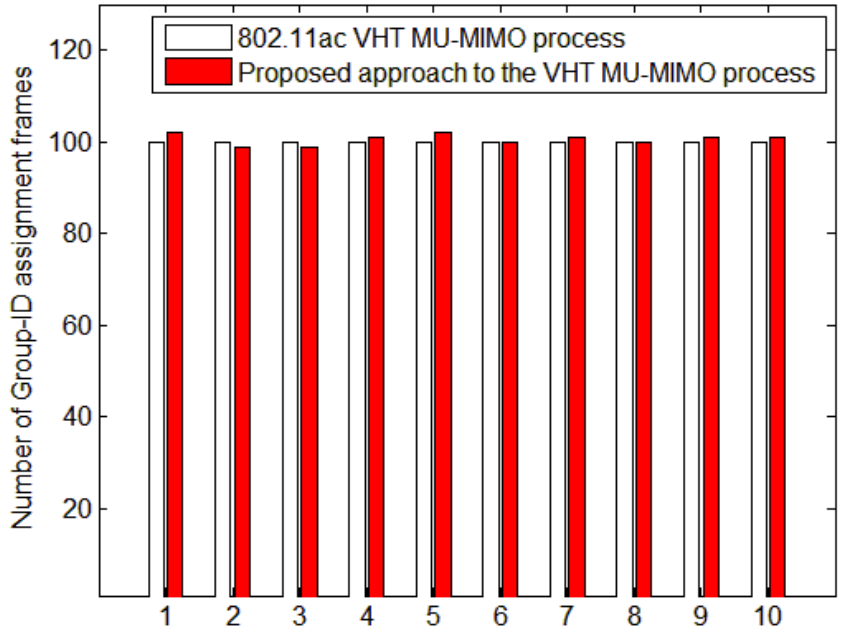




Simulation Results: Control and Management Frames

- Ten iterations with hundred random data streams:





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Conclusion

- Explored the VHT MU-MIMO communication mode with its supporting technologies.
- Proposed a solution to reduce wasting a portion of an A-MPDU of a short data stream in a group of unequal streams by concatenating longer data streams in consecutive groups.
- Considered selection of PPDU duration of a group as function of A-MPDU size and divided the A-MPDU of long data stream to the average of the entire group while the next consecutive Group ID is assigned within the A-MPDU.
- After the Block Acknowledgement procedure and Group ID assignment to new STAs, remaining data of the long data streams are transmitted together with the new data streams.
- Simulation results show significant improvement in transmission time and efficient space-time utilization of the channel with no additional overhead of control and management frames.

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[1] Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications. Amendment 4: Enhancements for Very High Throughput for Operation in Bands below 6 GHz, IEEE Standard 802.11ac, 2013.

[2] M. Gast, 802.11ac, *A Survival Guide*. Sebastopol, CA, USA: O'Reilly, 2013.

[3] C. Jiyoung, J. Hu, B. C. Jung, and D. K. Sung. "Performance comparison of downlink user multiplexing schemes in IEEE 802.11ac: Multi-User MIMO vs. frame aggregation," in *Proc. Wireless Communications and Networking Conference (WCNC)*, Paris, France, Apr. 2012, pp. 1514–1519.

[4] C. Chung, K. Chung, B. Kang, and J. Kim, "A-MPDU using fragmented MPDUs for IEEE 802.11ac MU-MIMO WLANs," in *Proc. TENCON 2013 IEEE Region 10 Conference*, Xi'an, China, Oct. 2013, pp. 1–4.

[5] D. Skordoulis, Q. Ni, H. Chen, A. P. Stephens, C. Liu, and A. Jamalipour, "IEEE 802.11n MAC frame aggregation mechanisms for next-generation high-throughput WLANs," *IEEE Wireless Communications*, vol. 15, no. 1, pp. 40–47, Feb. 2008.

[6] (October 9, 2014) Cisco. "802.11ac: The Fifth Generation of Wi-Fi Technical White Paper." [Online]. Available: http://www.cisco.com/en/US/prod/collateral/wireless/ps5678/ps11983/white_paper_c11-713103.html.

[7] E. H. Ong, J. Kneckt, O. Alanen, Z. Chang, T. Huovinen, and T. Nihtila, "IEEE 802.11ac: Enhancements for very-high throughput WLANs," in *Proc. IEEE Personal Indoor and Mobile Radio Communications* (*PIMRC 2011*), Toronto, ON, Canada, Sept. 2011, pp. 849–853.