Optimal PPDU Duration Algorithm for VHT MU-MIMO Systems

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***Abstract*—We propose an optimal Physical Layer Convergence Procedure Protocol Data Unit (PPDU) duration algorithm that divides a long data stream into two portions among consecutive groups based on the average PPDU duration of the Very High Throughput (VHT) group. The proposed solution considers all Wireless Local Area Network (WLAN) parameters and satisfies requirements of the VHT Multi-User Multiple Input Multiple Output (MU-MIMO) protocols. The simulation results show that the optimal PPDU duration algorithm offers significant improvements by accommodating traffic of additional STAs in shorter time and by efficiently utilizing the previously wasted sections of space-time streams.**

I. Introduction

Very High Throughput (VHT) Multi-User Multiple Input Multiple Output (MU-MIMO) systems allow an Access Point (AP) to simultaneously transmit data streams of multiple stations (STAs) over the same channel. The transmission time (TXTIME) of the process is selected based on the duration of the largest Physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU) among the STAs of a VHT group. It has been observed that this selection results in wasting space-time streams because STAs have unequal PPDUs.

The IEEE 802.11ac standard introduces the VHT MU-MIMO mode where an AP may simultaneously communicate with up to 4 STAs and maximum 4 data streams per STA. Special management frames have been introduced in order to support this communication mode. Using these frames, between 2 and 4 STAs are assigned a common VHT group ID and a unique user position ID per group. Having collected position parameters of the STAs using beamforming via the Sounding Protocol, the AP propagates transmission signals to the assigned group. The streams of a particular STA are only transmitted in its direction while they are nullified in other directions. At the end of a transmission, the reception of the streams is acknowledged by every STA [1], [2]. An example of a VHT MU-MIMO system is shown in Fig. 1.

During the VHT MU-MIMO transmission, the TXTIME of a VHT group over the shared media needs to be determined. Every data stream has a variable duration depending on the Aggregated Media Access Control (MAC) Protocol Data Unit (A-MPDU) size, constellation, and transmission rate. However, the standard selects by default the highest PPDU duration as the transmission duration for a VHT group [1], [2]. Due to the unequal durations of STAs data streams of the group, a considerable portion of a space-time stream is wasted for short PPDU data streams. We propose the optimal PPDU duration algorithm in order to reduce this waste. The algorithm involves the following steps: i) Taking average of PPDU durations of all STAs; ii) Selecting the STAs whose PPDU duration exceeds the average PPDU duration; iii) Increasing the value of A-MPDU (starting with 8,191 octets) while keeping unchanged all other parameters of the selected STAs until the calculated PPDU duration becomes larger (for a particular A-MPDU size) than the average PPDU duration of the STA; iv) Transmitting the amount of data of the selected STA that fits the A-MPDU size along with the Group ID management frame of the next group ID; v) After acknowledgement and Group ID assignment procedure, transmitting the remaining data with new STAs in the next assigned VHT group. The flow diagram of the proposed algorithm is shown in Fig. 2.

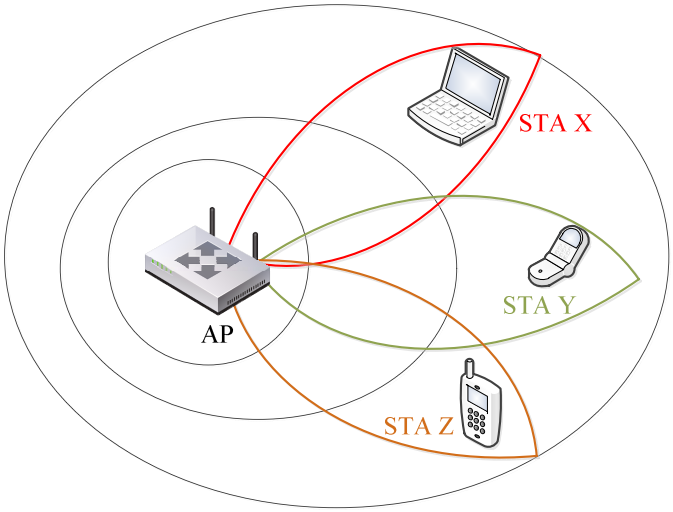

Fig. 1. VHT MU-MIMO system with three STAs.

II. Optimal PPDU Duration Algorithm

Previous proposals [3] were based on dividing data between VHT groups. The authors described the VHT MU-MIMO protocols, their relationships, and how the division of data-stream of an STA may be supported in VHT MU-MIMO systems under the assumption that some important parameters were constant. The algorithm proposed in this paper takes all parameters into consideration and is, hence, applicable to any combination of data-streams within a VHT group.

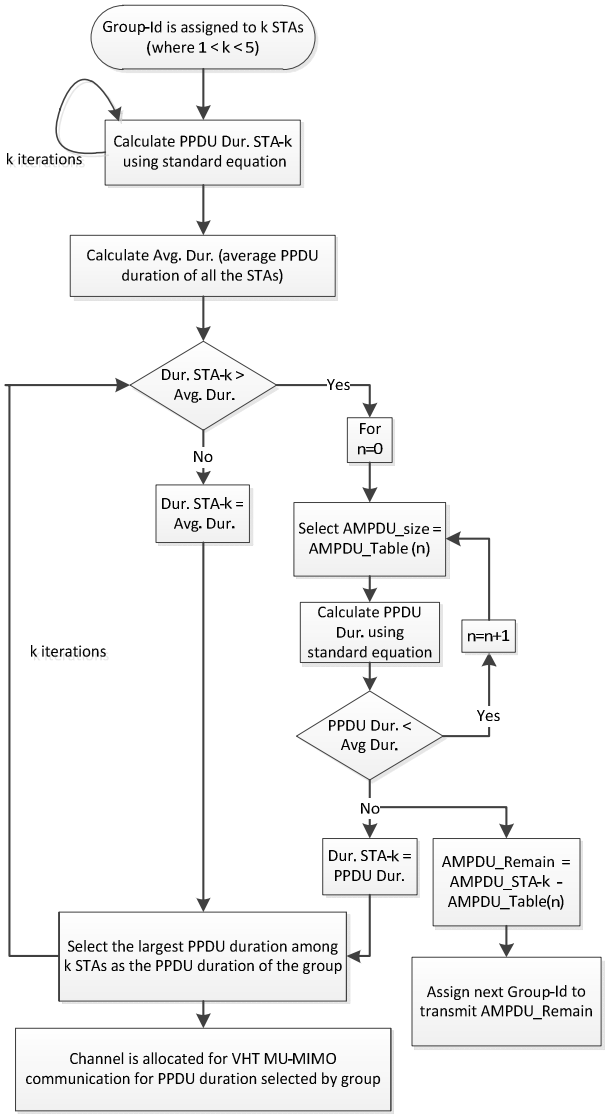

Fig. 2. Optimal PPDU duration algorithm: calculation of the TXTIME in VHT MU-MIMO systems.

III. Simulation Results

In order to quantify the improvements of the proposed algorithm, we designed a simulation testbed for VHT MU-MIMO communication process. A data stream generator randomly selects between 200 and 1,048,575 octets simulating the incoming STAs data streams. We first simulate transmission time of data streams using the standard VHT MU-MIMO communication process. The data stream with the largest PPDU duration determines the TXTIME of the group. We then simulate the transmission of data streams using the proposed optimal PPDU duration algorithm where A-MPDU of large space-time STAs is divided between VHT group IDs while considering the average PPDU duration of the group. Fig. 3 illustrates that TXTIME determined using the proposed algorithm significantly decreases as number of data streams increases. Fig. 4 and Fig. 5 illustrate the results of 10 simulations where portions of short data streams that were previously wasted are utilized by transmitting data of other STAs.

IV. Conclusion

We proposed an optimal PPDU duration algorithm that reduces waste of space-time streams thus significantly improving transmission time of the VHT MU-MIMO communication process.

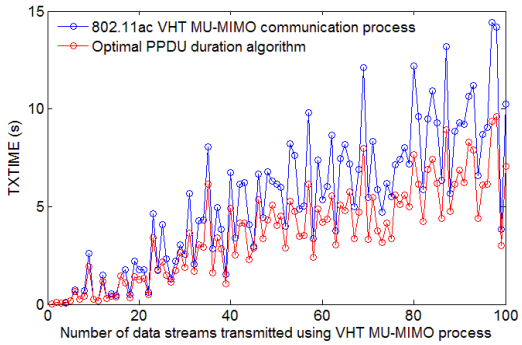

Fig. 3. Performance comparison of standard VHT MU-MIMO system and the proposed optimal PPDU duration algorithm.

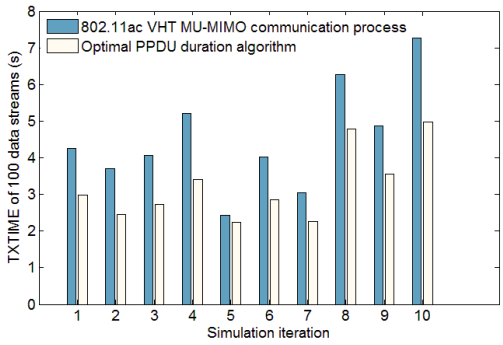

Fig. 4. Performance comparison of 10 simulations showing transmission times of 100 STAs.

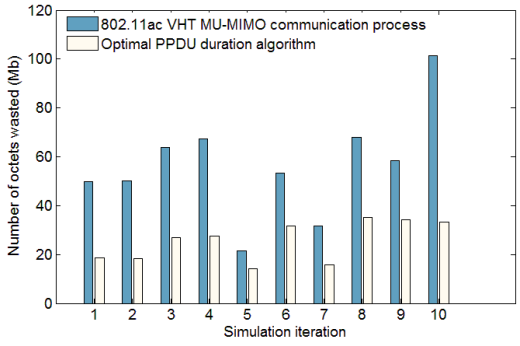

Fig. 5. Performance comparison of 10 simulations showing wasted portions of space-time streams of 100 STAs.

References

[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] E. Perahia and R. Stacey, *Next Generation Wireless LANs*, 2nd ed. New York, NY, USA: Cambridge, 2013, pp. 419–439.

[3] A. Syed and Lj. Trajković, "Improving VHT MU-MIMO communications by concatenating long data streams in consecutive groups," in *Proc. 2015 IEEE Wireless Communications and Networking Conference Workshops*, New Orleans, LA, USA, Mar. 2015, pp. 107–112.