QUICK: Pursuing Qualified CSI for MU-MIMO Networks

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1. INTRODUCTION

MU-MIMO is an emerging wireless technology that allows concurrent data transmission between multiple users and a multi-antenna access point (AP). However, a larger amount of erroneous packets often occur in the MU-MIMO streams, resulting in massive retransmissions and severe transmission lags. Two primary reasons behind this anomaly are inaccurate channel estimation and the channel access overhead that is associated with Channel State Information (CSI) feedback. Prior researches mainly focus on the data errors caused by low SNR. Nevertheless, incorrect CSI estimations impede correctly decoding packets from concurrently transmitted signals in MU-MIMO networks. On the other hand, most existing solutions in reducing CSI feedback overhead focused on feedback compressing or distributed user selection [3]. The benefits of these algorithms are only realized after the transmission mode and group are selected. OPUS [2] reduces CSI overhead via the AP iterative probing.

In this paper, we propose QUICK a validation check based CSI recovery and feedback protocol for MU-MIMO. QUICK is practical and fully compatible with current 802.11ac WLAN frameworks. We implement QUICK over off-the-shelf WiFi devices. Extensive experiment results demonstrate that QUICK substantially improves the throughput for MU-MIMO WLAN systems (*e.g.*, more than 5× for 2×2 uplink MU-MIMO).

2. QUICK DESIGN

2.1 CSI recovery

QUICK corrects two types of CSI errors as follows:

(1) CFO: For a client with CFO, say B, it receives Rx_b from AP. If the difference between Rx_b and Tx_b is only caused by the CFO of the channel between the AP and B, the packets B receives is not "ruined" by other clients. The CSI phase offset caused by CFO ONLY is $\overline{h_b}(t) = h_b e^{j\Delta\phi_{b,t}}$, which can be treated as the time delay in phase [1]. Hence, this client can estimate the CSI phase offset it experiences according to the differences between Rx_b and Tx_b. $Rx_b = Tx_b * e^{-j\Delta\phi} + N$, where N is the gaussian noise.

Hence, we can estimate the phase offset by $e^{-j\Delta\phi} = \frac{Rx_b}{Tx_b} - \frac{1}{SNR} \approx \frac{Rx_b}{Tx_b}$. That is to say, we mitigate the impact of CFO without eliminating it.

(2) Low SNR: Signal combining is a well-known technique in wireless communication and is used to provide spatial and temporal diversity. Signal combining leverages multiple receptions of the same data to get a better estimate of the received signal. We combine training sequence after demodulation.

2.2 SCI Feedback Reduction

We eliminate unnecessary CSI feedback by checking its validity period. The main difference between QUICK and OPUS [2] is that these CSI may be used for the next several times transmission rather than only the next one.

The key technique in QUICK is how to verify the effectiveness of the historical recorded CSI. The stable statistical information (*e.g.*, variance) in a short term means the similarity between the historical CSI (H_l) and newly calculated CSI (H_n). Recall the basic communication model $Y{=}HX{+}N$, and $N \sim \mathcal{CN}(0, \sigma^2)$. Consider a random variable: $\mathfrak{Y} = Y_n - Y_l = (H_n - H_l)X + (N_n - N_l)$. We use $D(\mathfrak{Y}_{eq})$ to denote the variance of $\mathfrak{Y}$ under $H_n = H_l$. Hence, we can verify whether the CSI is valid by checking the ration of $\sigma_1^2 = D(\mathfrak{Y}_{test})$ and $\sigma_2^2 = D(\mathfrak{Y}_{eq})$. If $\frac{\sigma_1^2}{\sigma_2^2} \approx 1$, we can infer that H_n is as close as possible to H_l.

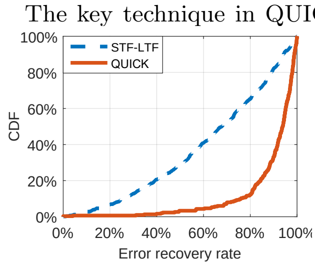

Figure 1: Recovery rate.

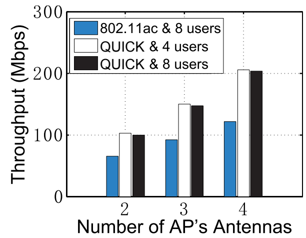

Figure 2: Throughput.

3. IMPLEMENTATION AND EVALUATION

The prototype QUICK is comprised of USRP-N210 and USRP-X310 radio platforms and corresponding UHD software packages. A 2-antenna AP is built over one USRP-X310 plus two SBX daughterboards. We use two USRP-N210 platforms as 2 concurrent clients. Each USRP-N210 is equipped with a SBX daughterboard, providing 40 MHz bandwidth. The entire system operates following the IEEE 802.11a protocol and is compatible with standard OFDM specifications.

We first evaluate the performance of QUICK's CSI recovery under CFO by comparing it with that of conventional STF&LTF schemes. Fig. 1 shows the CSI error recovery in a mobile scenario, in which the client moves at the normal human walking speed. We find that QUICK has a much higher error recovery rate than the STF&LTF scheme.

We plot the throughput gain coming from CSI reusing in Fig. 2.

4. REFERENCES

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