Poster: LATTE: Online MU-MIMO Grouping for Video Streaming Over Commodity WiFi

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ABSTRACT

In this paper, we present LATTE, a novel framework that proposes MU-MIMO group selection optimization for multi-user video streaming over IEEE 802.11ac. Taking a cross-layer approach, LATTE first optimizes the MU-MIMO user group selection for the users with the same characteristics in the PHY/MAC layer. It then optimizes the video bitrate for each group accordingly. We present our design and its evaluation on smartphones over 802.11ac WiFi.

CCS CONCEPTS

• **Computer systems organization**; • **Networks** → **Cross-layer protocols**;

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1 INTRODUCTION

Multi-User Multiple-Input and Multiple-Output (MU-MIMO) in 802.11ac is a technique that improves spectral efficiency by allowing concurrent transmission between a single Access Point (AP) and multiple clients. Because it allows concurrent downlink transmissions to multiple clients, MU-MIMO has a significant potential benefit. However, if the wrong users/receivers/clients are grouped together in MU-MIMO transmission, the grouping protocol may introduce higher delays and lower throughput (high packet losses). Recent studies experimentally demonstrated that it is not uncommon for MU-MIMO to under-perform Single-User-MIMO (SU-MIMO) in various scenarios [4]. In this paper, we focus on multi-user video streaming applications over 802.11ac in a practical network. Video streaming techniques rely on Adaptive Bitrate (ABR) schemes to adjust the video playback for a diverse set of user devices and network conditions. The current ABR video streaming techniques are mostly designed for a single-user setting. Despite a plethora of work on improving single user QoE, when multiple users are competing for the network resources, it has been shown that these schemes may result in video bitrate oscillation, network resource underutilization, or QoE unfairness among users. In mobile and wireless networks, a user adjusts the video quality based on the measured throughput that depends on their available downlink transmission rate. Since the transmission rate for each user is determined by wireless resource allocation schemes in the physical layer, an application-agnostic and/or unfair resource allocation in the MAC layer inevitably results in poor QoE. To solve the aforementioned performance degradation in both MU-MIMO MAC grouping and QoE in the application layer over WiFi, we propose a cross-layer approach, LATTE which is *a dual-phase* framework for multi-user video streaming over IEEE 802.11ac. LATTE targets MU-MIMO group selection optimization in the MAC layer, which not only provides higher speeds (~433 to 1733 Mbps in practice) but also supports simultaneous transmission to multiple users at the same time. However, if the WiFi AP selects the incorrect users to group in a MU-MIMO transmission, it may introduce high delays and lower throughput. In addition, factors affecting MU-MIMO user grouping can consequently sabotage the performance of multi-user applications over 802.11ac/ax. By taking such factors into account, we first propose a Reinforcement Learning (RL)-based MU-MIMO group and mode optimization. We then propose a QoE optimization of ABR video streaming over WiFi using Lyapunov optimization technique [1]. A user moving at walking speed may result in a significant change in the channel. Therefore, the goal of LATTE is to take into account such external factors (e.g., user mobility and device chipset characteristics) that typically are not considered in conventional methods when designing QoE optimization algorithms over WiFi. Based on our experiments, LATTE can improve the QoE of multiple users even if their channel quality is unstable due to the undesirable external factors.

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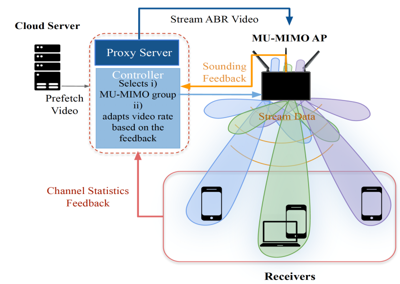
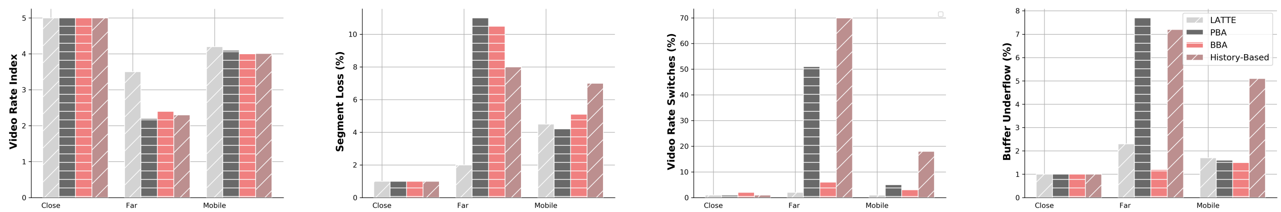


Figure 1: LATTE Framework Overview.

2 SYSTEM DESIGN AND RESULTS

LATTE Overview As shown in Figure 1 the proposed approach has a cross-layer nature in which the application layer and the wireless layer interact with each other to ensure support for heterogeneity while maintaining high content quality. In network level optimization, our approach aims to save bandwidth, increase throughput, and reduce delay. The proxy server pre-fetches video segments of available video rates from the cloud for streaming to the receivers. The



(a) (b) (c) (d)

Figure 2: Experimental results for different algorithms under various experimental scenarios with phones: (a) average video rate, (b) percentage of lost segments, (c) percentage of slots with video rate switches, (d) percentage of slots with buffer underflows.

video data is transmitted to the WiFi AP. The Controller in LATTE maintains statistics of QoE performance at each receiver. It collects periodic feedback reports from receivers. The LATTE Controller is responsible for adjusting the video rate (at the server) and the transmission rate (via the AP). The receivers listen to the video stream packets, collect and calculate the performance statistics, play the video, and send the statistics back to the Controller.

DUAL-PHASE Optimization Framework

Phase I In Phase I, we propose an RL-based MU-MIMO grouping and mode selection in the MAC layer [3] that takes into account not only the conventional factors that impact MU-MIMO grouping such as SNR, number of spatial streams but also external factors such as number device characteristics and user mobility (the motion of individual users can be tracked by reading their explicit Channel State Information (CSI)). By considering these factors as the input to the RL agent, LATTE learns how to optimize the MU-MIMO grouping and mode selection for each environment such that the downlink throughput is maximized.

Phase II The underlying streaming algorithm adjusts the transmission and video rates in Phase II based on the desired QoE metrics specified by network operators or receivers. In doing this, LATTE formulates the QoE optimization problem for MU-MIMO aware wireless video streaming as a utility maximization problem using Lyapunov technique. For maximizing QoE, the average video rate is maximized while meeting some constraints on the three QoE factors (segment losses, buffer underflows, and video rate switches). The QoE optimization problem, when the channel state indicator variable $S_i^t(r)$ which indicates whether the transmission at rate r is successful, is formulated as follows:

$$\max \quad \frac{1}{T}\sum_{i=1}^{N}\sum_{t=1}^{T} q(v_t) S_t^i(r_t)$$

Results We build a testbed that is consists of one commodity 802.11ac AP and multiple Nexus phones. In all our experiments, we used the 20 MHz bandwidth on the 5GHz channel and the 802.11ac standard. To perform Phase I, we modified the AP to send information from sounding period and the transmit SNR a receiver to a Linux host. The host PC takes such information as input and performs the RL-based MU-MIMO grouping. The RL agent decision on MU-MIMO grouping for individual receivers is sent back to an implemented MU-MIMO grouping algorithm in the AP. After forming the MU-MIMO group in Phase I, the AP streams the video chunks to the target group. The performance of LATTE is evaluated for the following settings: (a) Close: all receivers are randomly placed within 1m from the AP, (b) Far: all receivers are randomly placed far (at least 10m away) from the AP, and (c) Mobility: all receivers are mobile. We pre-encoded a video at five different video rates ranging from 1 Mbps to 8 Mbps. We compare the performance of LATTE to the following state of the art algorithms: (i) BBA (Buffer Based Adaptation) [2], (ii) PBA (Prediction Based Adaptation) [5], (iii) History-Based: A simple heuristic that sets the video rate to the maximum rate at which all receivers successfully receive the video. Figure 2 shows the performance of LATTE and other algorithms for different experimental scenarios. As shown, For the Far case, LATTE achieves 1.5x higher video rate than other algorithms. The percentage of segments lost for LATTE is less than 2% which is 4x less than other algorithms. For the Mobility scenario, LATTE yields higher video rate than other algorithms. In Far and Mobility scenario due to low SNR and mobility, all the devices run on SU mode while for the near scenario, the devices run in MU mode. As we can see across all the scenarios LATTE shows a more stable performance in application layer due to the proper MU-MIMO group and mode selection in MAC layer. Therefore, our early results demonstrate that multi user applications can benefit from *correct* MU-MIMO grouping in the MAC Layer. In the future work, we would perform an in-depth analysis to understand the impact of simultaneously running other applications along with video streaming on our system, interference, and also to compare the performance of devices with different characteristics on both SU and MU mode in a large scale setting to understand factors such as fairness and delay.

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