EliMO: Eliminating Channel Feedback from MIMO

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MIMO Needs CSI Feedback

- MIMO beamforming provides high throughput for WiFi

To achieve high beamforming performance, feedback of Channel State Information (CSI) is needed.

- Implicit or Explicit CSI Feedback
Implicit CSI Feedback

- AP measures ACK’s LTF from STA to get uplink CSI
- AP uses the transpose of uplink CSI as downlink CSI

- Downlink CSI ($H_d$) and uplink CSI ($H_u$) are not reciprocal, leading to low SNR.

$\tilde{H}_d$ and $\tilde{H}_u$: over-the-air channels

$H_d$ and $H_u$: baseband-to-baseband channels

$A_t$, $A_r$, $B_t$, & $B_r$: digital baseband channels
Explicit CSI Feedback

- STA measures NDP’s LTF to get downlink CSI
- STA sends measured downlink CSI to AP

Measuring and transmitting CSI introduce high computation & communication overhead
Eliminating CSI Feedback

- Can we completely eliminate explicit CSI feedback?
  - And achieve as high SNR as explicit CSI feedback
  - With as low overhead as implicit CSI feedback

- **ELIMO**: two-way CSI estimation for WiFi
  - AP estimates downlink CSI without explicit CSI feedback
  - STA does not send CSI to AP
Outline

- Introduction
- EliMO Two-way CSI Estimation
- EliMO Protocol Design
- Evaluation
- Conclusions
Two-way CSI Estimation

- Two-way CSI $H_{tw}$ Estimation:
  \[ H_{tw} = \text{MMSE}(X,Y_f) \]

- Downlink CSI $H_d$ Estimation:
  \[ H_{tw} = H_u H_d \rightarrow H_d = (H_u)^+ H_{tw} \]

- Uplink CSI $H_u$ Estimation:
  \[ H_u = \text{MMSE}(X,Y_u) \]
STA only needs to amplify and send FTF to AP
- No need for STA to measure downlink CSI: reduced computation
- No need for STA to send CSI to AP: reduced communication
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Packet Format

- Implementing two-way CSI estimation in 802.11n/ac
  - FTF: Feedback Training Field, received signals of LTF
  - FTR: Feedback Training Request/Response

802.11n mixed mode packet

802.11ac packet
AP sends LTF and FTR to STA
- STA puts received LTF, amplify it, and put it in FTF
- STA sends LTF, FTR, and FTF to AP
- AP computes downlink CSI $H_d$, which is used for sending the next data packet
Dealing with Stale CSI

- Downlink CSI could be stale: $\Delta t_1 + \Delta t_2$ is too large
- AP sends NDP (w/ FTR) to request STA to measure downlink CSI, when
  - either similarity of two recent CSI measurements is smaller than 0.98
  - or the time from the previous ACK ($\Delta t_2$) is larger than 100ms
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Evaluation Setup

- AP & STA are laptops with Intel WiFi Link 5300 installed
  - The power signal of WiFi chipset can not be programmed to “amplify and transmit” in slide 7. So we use trace-driven simulation.

- Downlink/uplink CSI traces ($H_d$ & $H_u$)
  - Frequency: 5GHz; channel width: 20MHz
  - AP: 3 external antennas;
  - STA: 3 internal antennas
  - Transmitting power: 17/15dBm for the AP/STA

- Scenarios
  - Static: both AP and STA are static
  - Mobile: the STA is randomly moving (~1.2m/s); the AP is static
EliMO achieves as high SNR as explicit CSI feedback, with as low overhead as implicit CSI feedback.
When static, EliMO’s throughput is 5X/4X/1.7X of “Implicit”, “Explicit per 1pkt", and “Explicit per 10pkts".

- “Explicit per 10pkt” means one explicit CSI feedback for every 10 data packets

When mobile, these numbers are 3.6X/4.5X/1.4X
When static, EliMO's energy consumption is 85%/30%/50% of that of “Implicit”, “Explicit per 1 pkt”, and “Explicit per 10 pkts”.

When mobile, these numbers are 90%/17%/57%.
Related Work

- Compressed CSI feedback, but still need CSI feedback
  - The same CSI for multiple packets, subcarriers, and/or antennae. [MobiCom’13]
  - Less bits to represent CSI [MobiCom’13]
  - Less frequent CSI feedback [CoNEXT’14]

- No CSI feedback
  - Echo-MIMO [IEEE TOSP’08] is similar to us, but not compatible with WiFi.
    - Narrow-band channels without frequency-selective effects
    - Over-the-air channels, not digital baseband channels
    - Pure theoretical analysis, not in a WiFi compatible protocol, not tested with real devices
Conclusions

- EliMO uses two-way CSI estimation and Feedback Training Field to accurately estimate downlink CSI without explicit CSI feedback.
- EliMO is WiFi compatible.
- EliMO significantly reduces computation, communication, and energy overhead for WiFi receivers.

This work has been supported by NSF CNS-1253506 (CAREER) and CNS-1553272 (CAREER).