Practical MU-MIMO User Selection on 802.11ac Commodity Networks

Sanjib Sur

Ioannis Pefkianakis, Xinyu Zhang and Kyu-Han Kim

UNIVERSITY OF WISCONSIN–MADISON

Hewlett Packard Labs

From Legacy to Gbps Wi-Fi

What is new in 802.11ac?

1999-2003 | 2009 | 2013

Legacy 802.11**a/b/g**:
Speeds up to **54 Mbps**

HT 802.11**n**:
Speeds up to **600 Mbps**

VHT 802.11**ac**:
Speeds **> 6 Gbps**

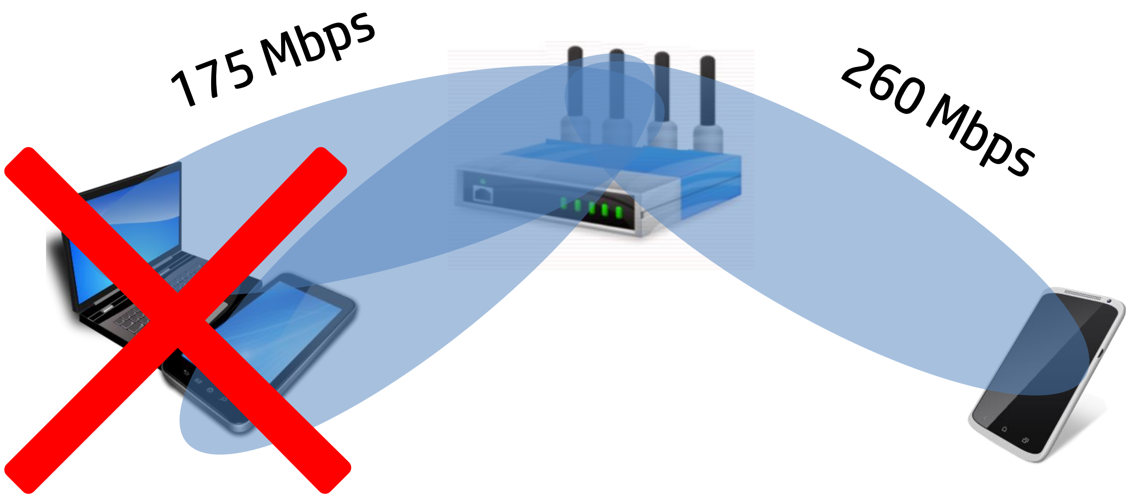
Channel bandwidth	Tx/Rx antennas	Modulation & coding	Device type	Data rate
40 MHz	1x1	256-QAM, 5/6	Smartphone, Tablet	200 Mbps
40 MHz	3x3	256-QAM, 5/6	Laptop	600 Mbps
80 MHz	1x1	256-QAM, 5/6	Smartphone, Tablet	433 Mbps
80 MHz	2x2	256-QAM, 5/6	Laptop, Tablet	867 Mbps
80 MHz	3x3	256-QAM, 5/6	Laptop	1.3 Gbps
160MHz	4-ant AP / 4, 1-ant STAs (**MU-MIMO**)	256-QAM, 5/6	Smartphone, Tablet	3.39 Gbps
160MHz	8-ant AP / 4, 2-ant STAs (**MU-MIMO**)	256-QAM, 5/6	Laptop	6.77 Gbps

Multi-User MIMO Feature on 802.11ac

- A MU-MIMO access point transmits multiple data streams *concurrently* to different receivers

MU-MIMO User and Rate Selection

- *User selection* determines which users to serve concurrently
- *Rate selection* determines the best link speed for each users

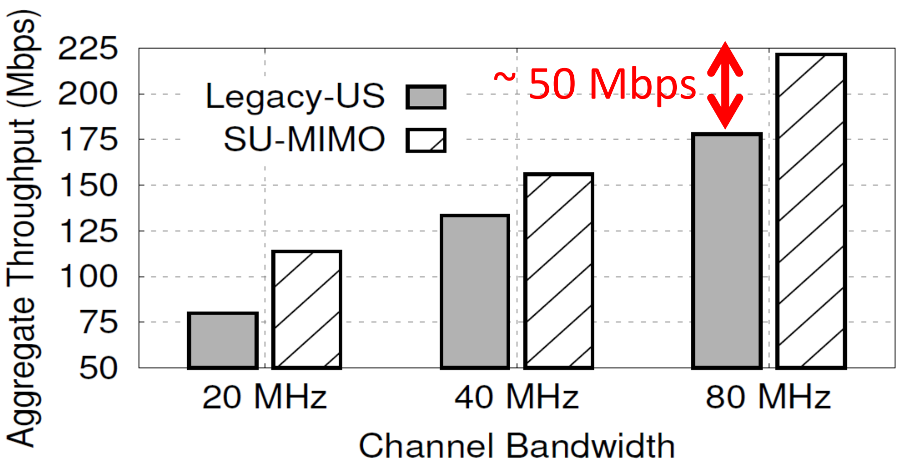


User and *rate selection algorithms* are fundamental for MU-MIMO performance

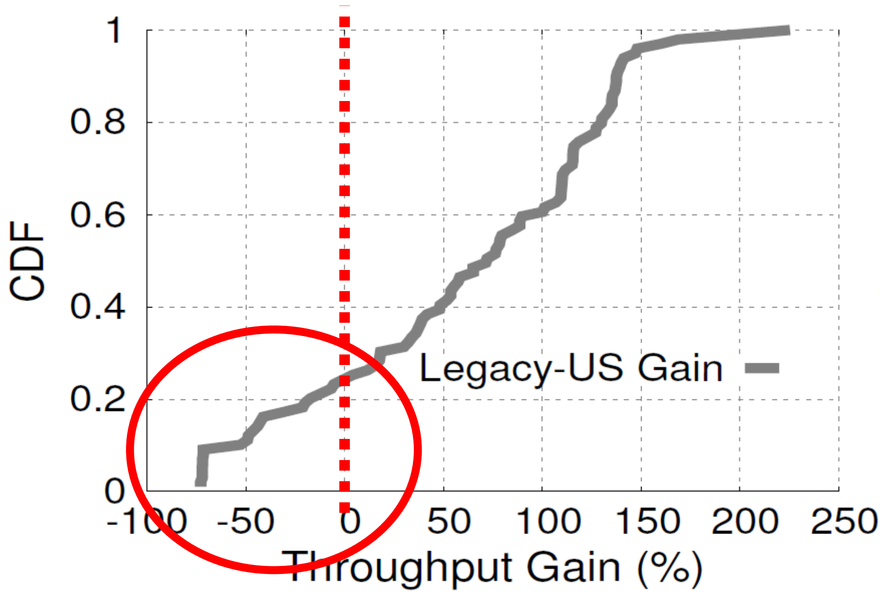
Practical MU-MIMO Performance

Commodity Access Point

802.11ac Users



Throughput drops when MU-MIMO is enabled!



MU-MIMO gain can be even lower than SU-MIMO in some enterprise settings

Outline of Today's Talk

- Why commodity APs *avoid* state-of-the-art solutions?

- How can we design a *robust and practical* MU-MIMO user and rate selection solution?

- What is the impact of our design and *real-time* implementation?

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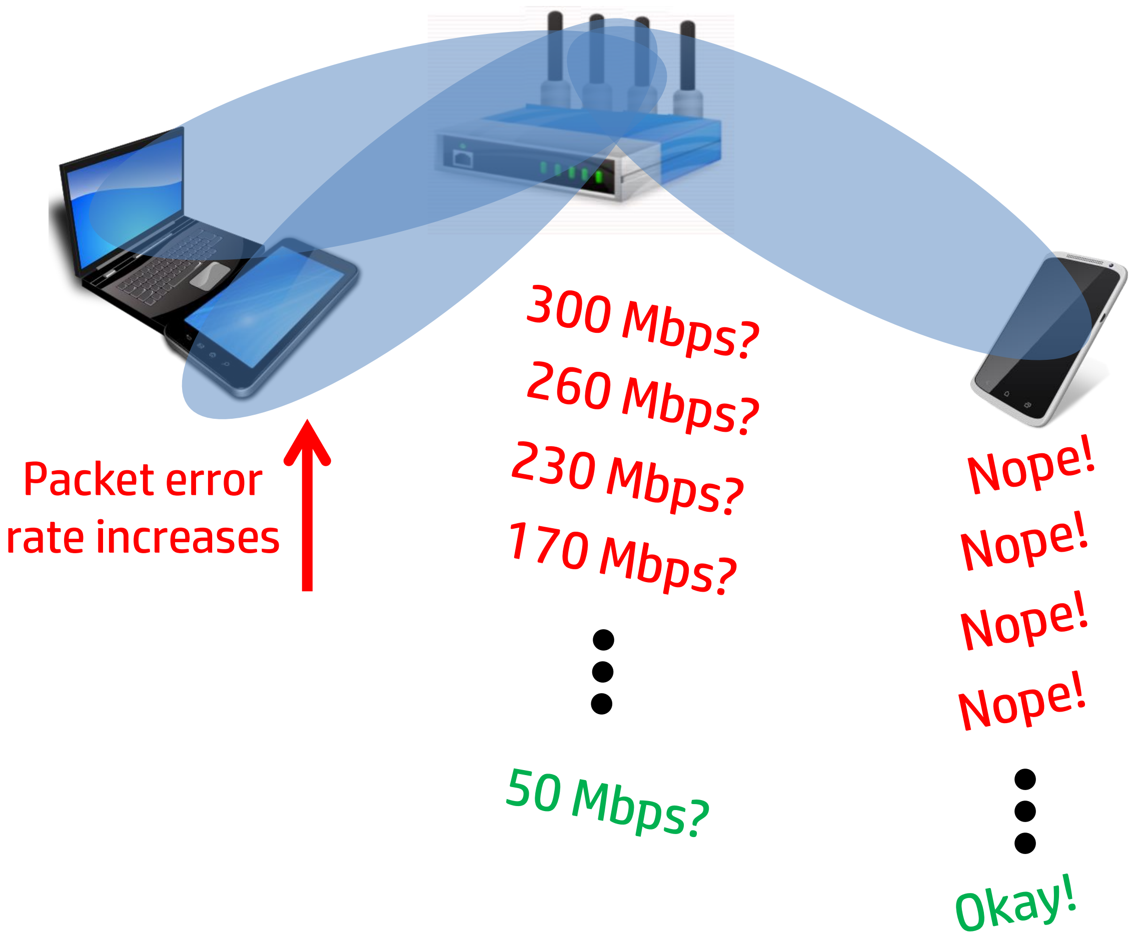
Algorithms on Commodity APs

- Both user and rate selection solutions are *trial-and-error* based



Statistics-based Adaptation

Problems:

High convergence time

Poor group formation

Limitations of State-of-the-Art Solutions

- Existing solutions rely on *full wireless channel feedback* for user and rate selection

- Heterogeneous bandwidth users *limit grouping opportunities*

- Limited resources on APs cannot support *computationally and memory expensive operations*, required by existing solutions

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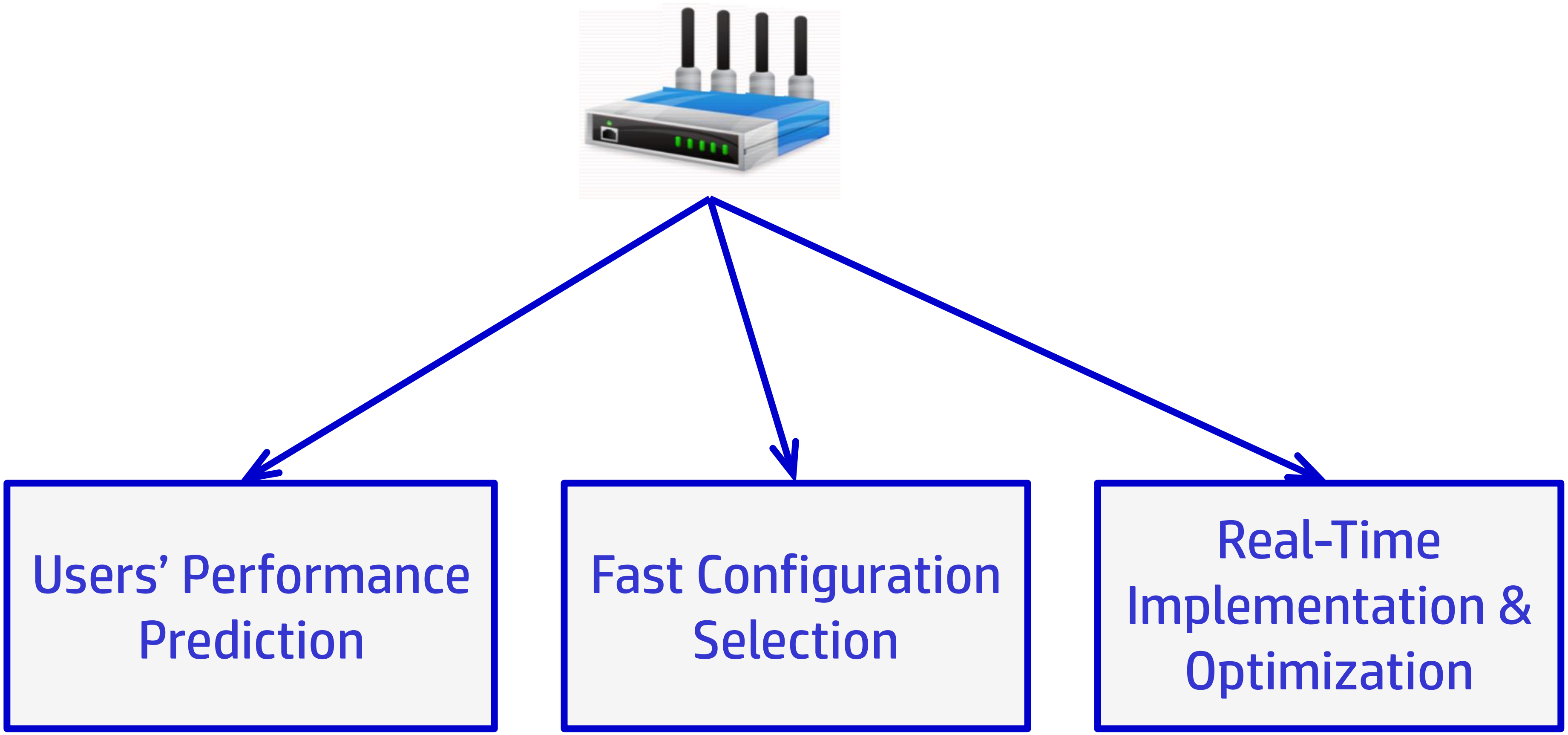
Our Solution: MUSE

- A practical MU-MIMO user and rate selection for 802.11ac commodity devices



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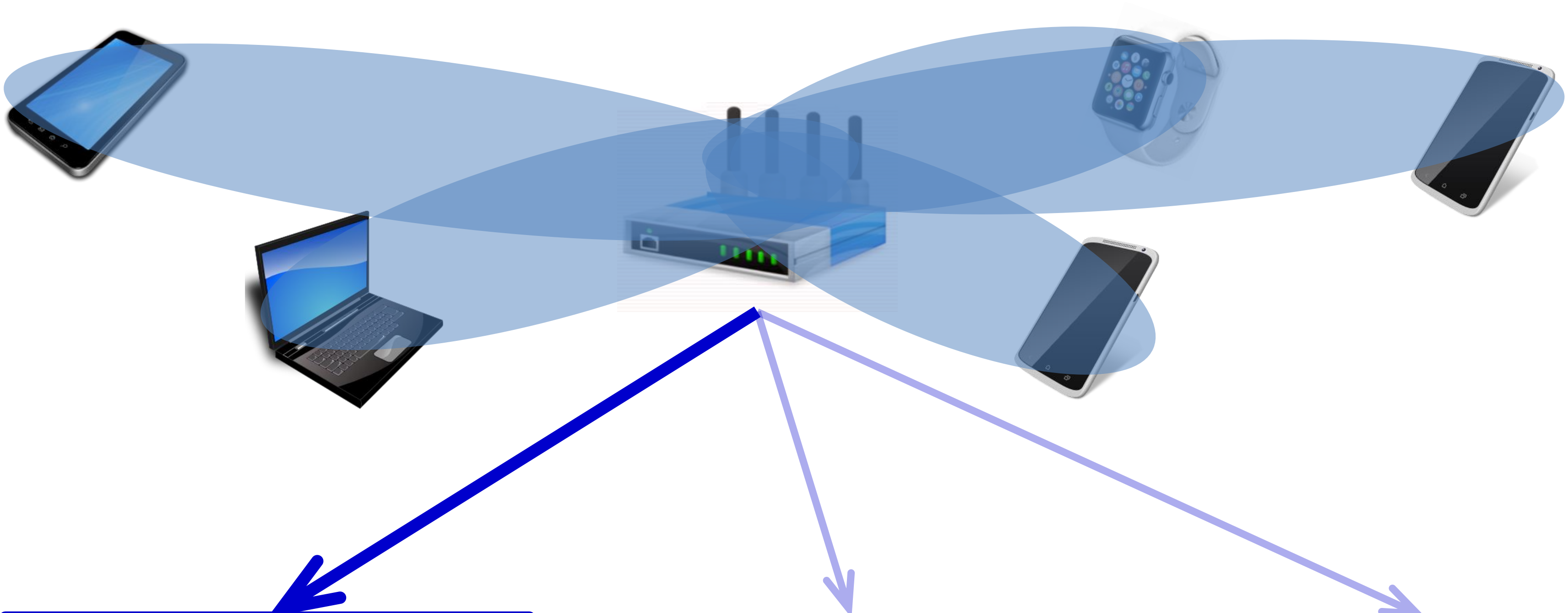
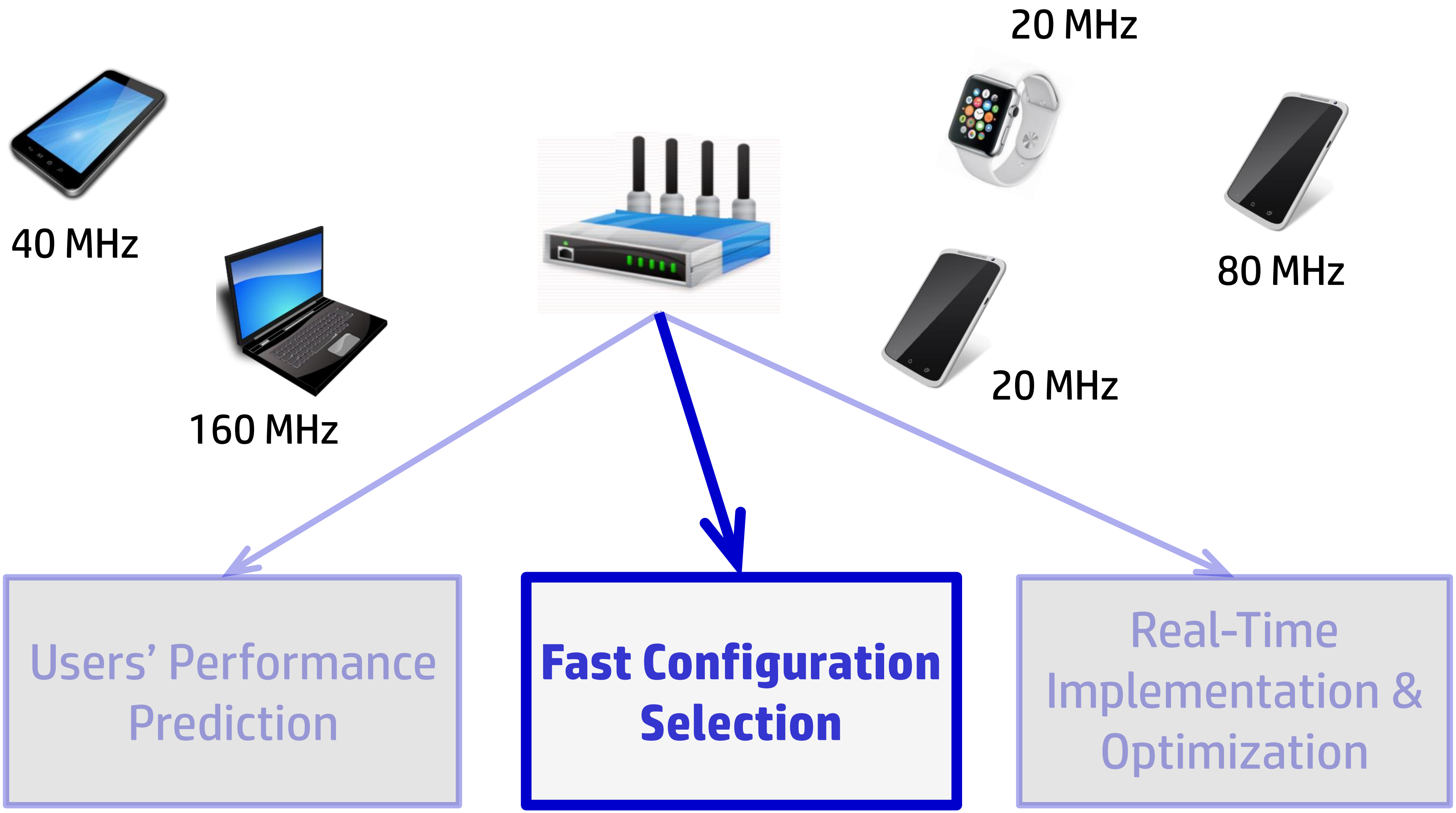


Users' Performance Prediction

Fast Configuration Selection

Real-Time Implementation & Optimization

Our Solution: MUSE



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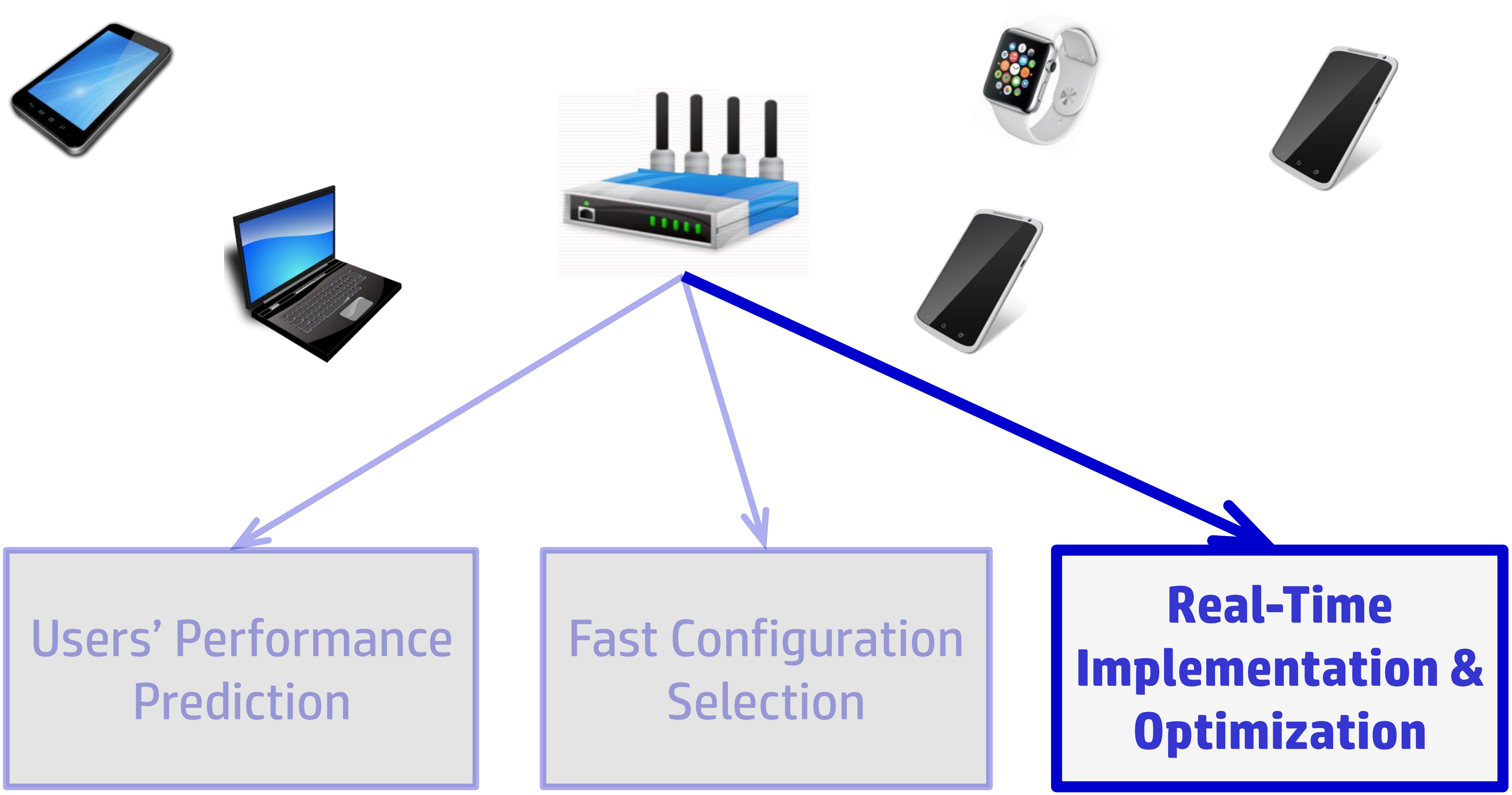

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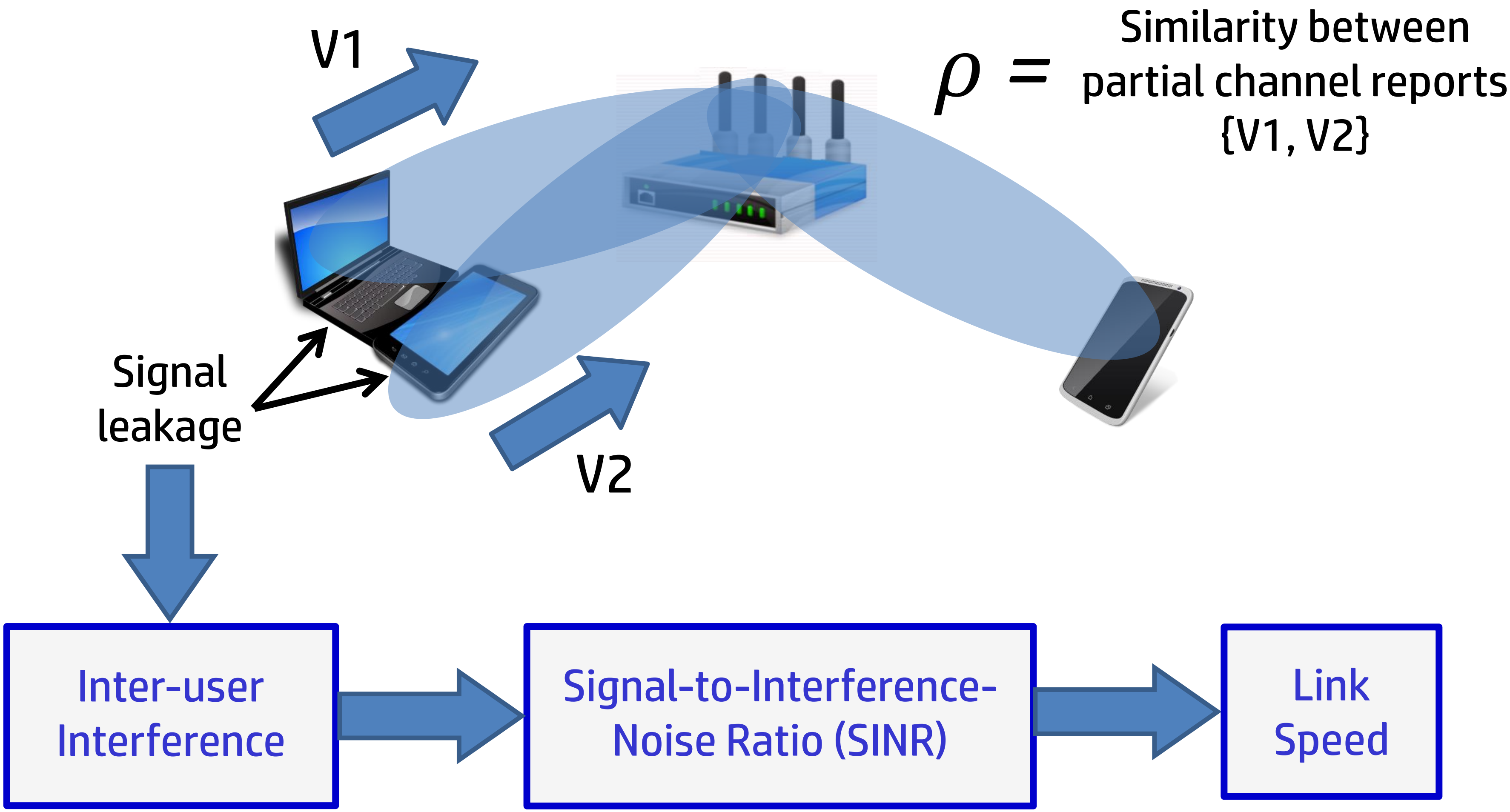
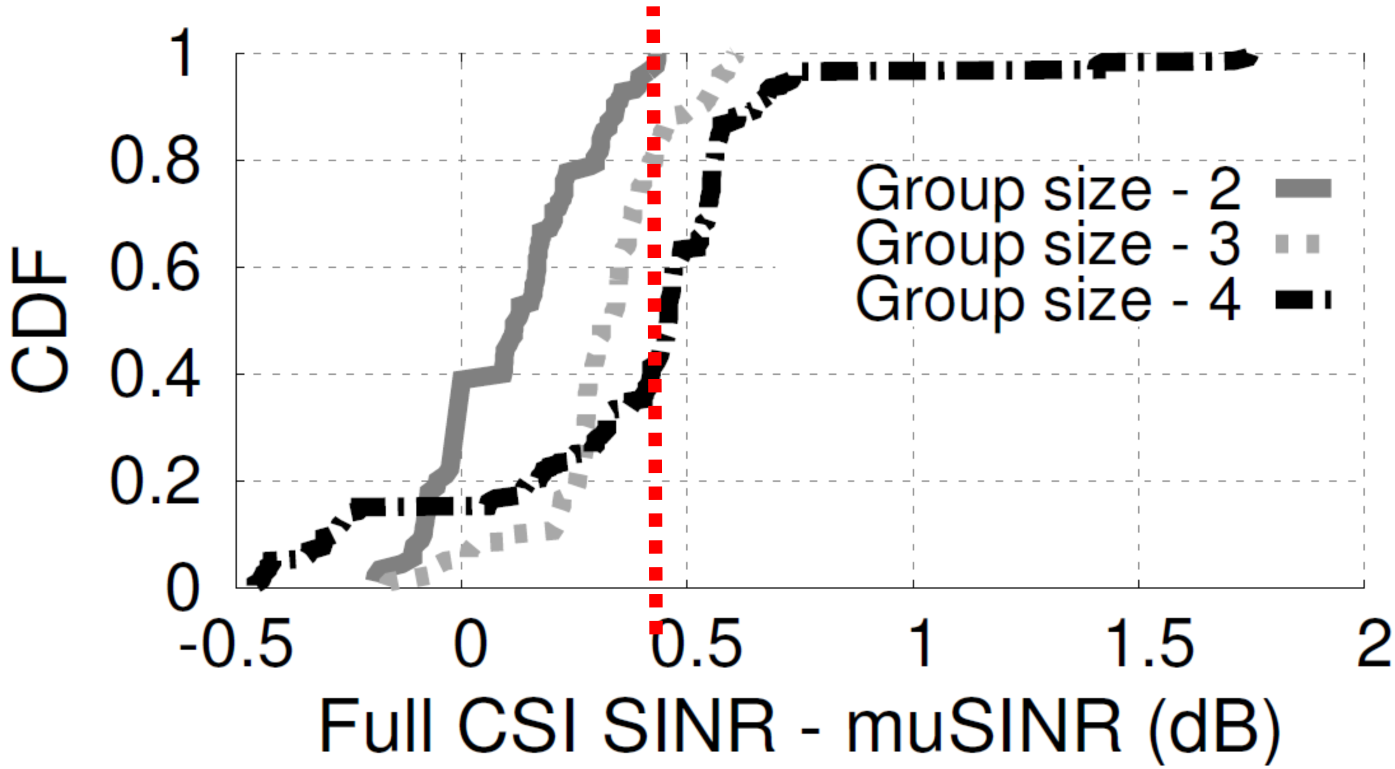


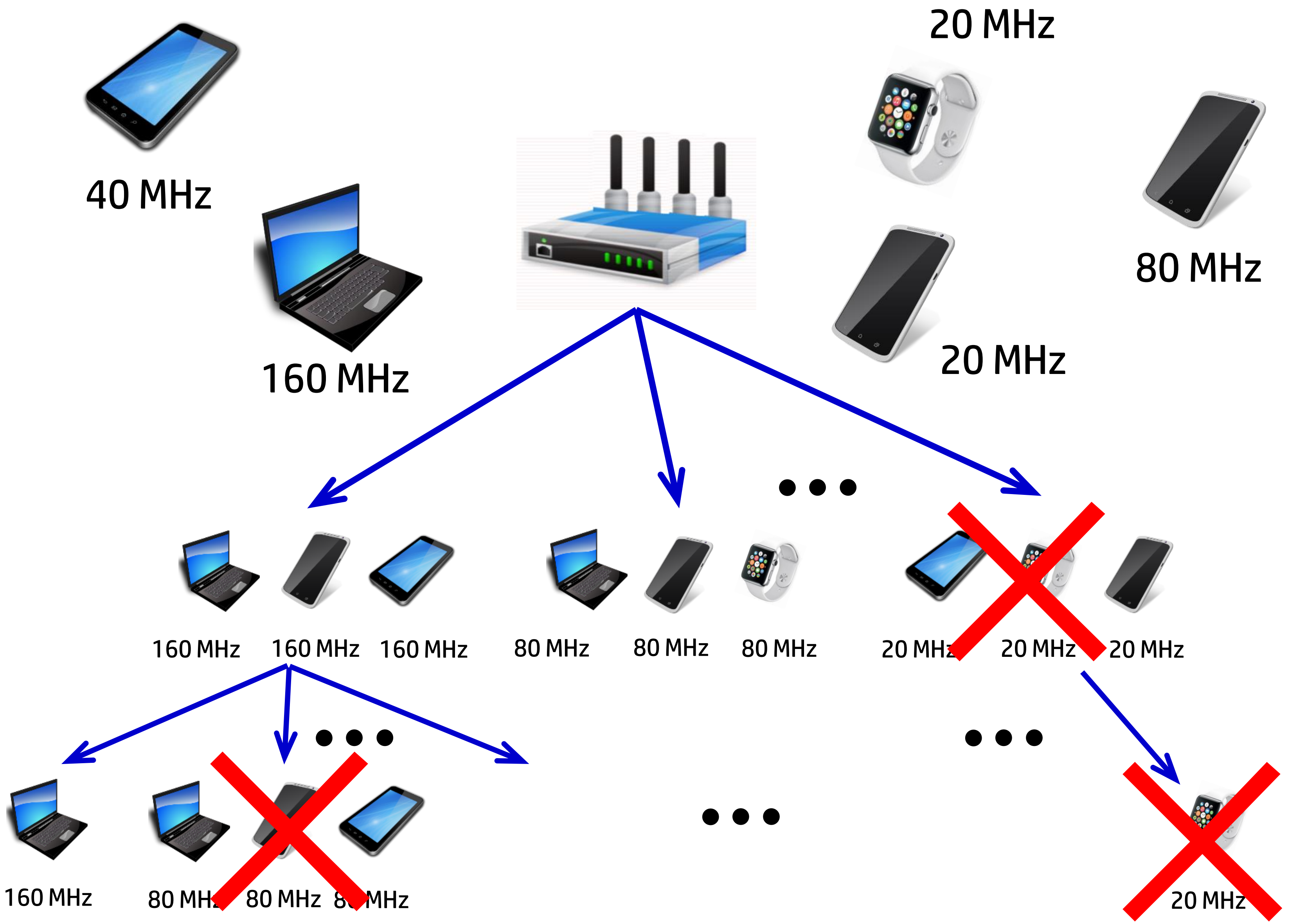
MUSE Predictable SINR Accuracy

- Comparison between MUSE predictable SINR with *full channel feedback* SINR



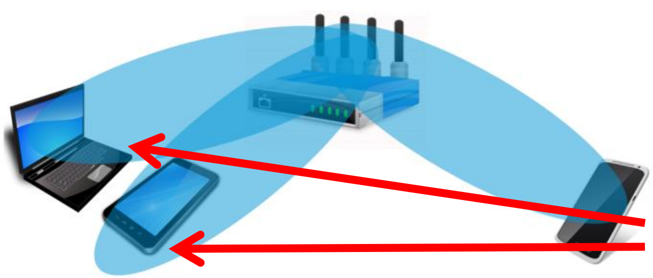
Median prediction error ~ 0.5 dB!

Fast Configuration Selection

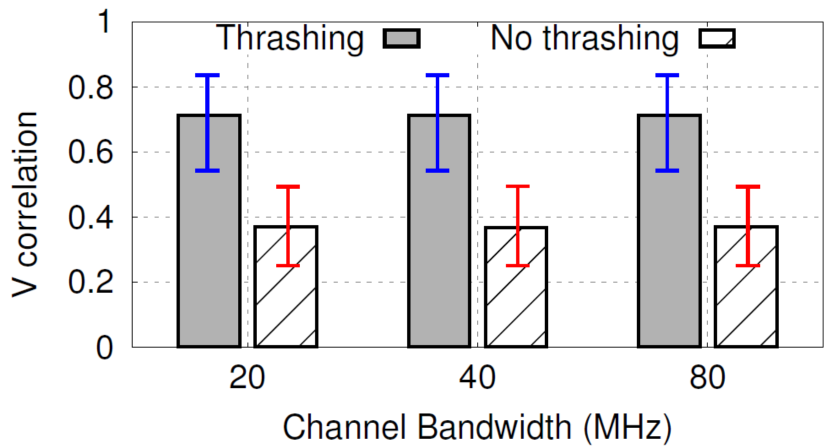


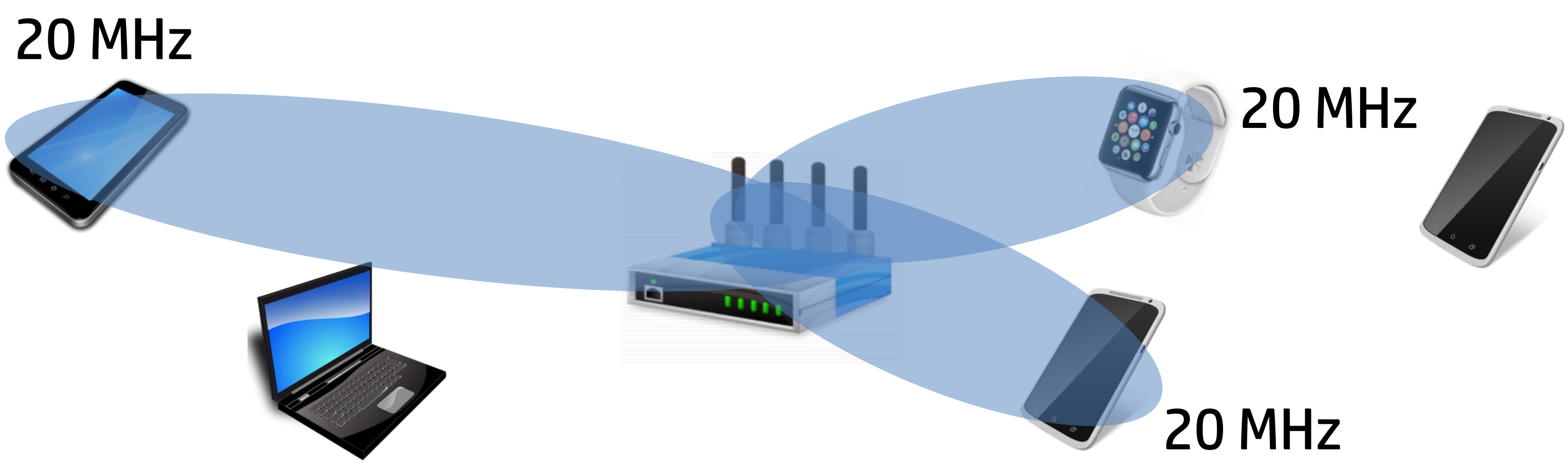
Fast Configuration Selection

- Partial channel report *correlation remains unaffected* irrespective of the channel bandwidth



Correlation between two users





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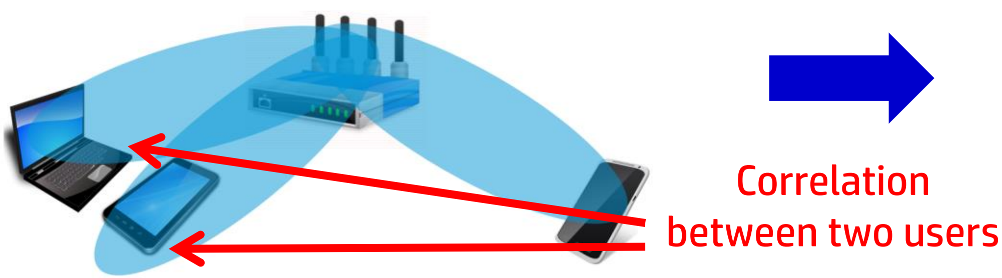

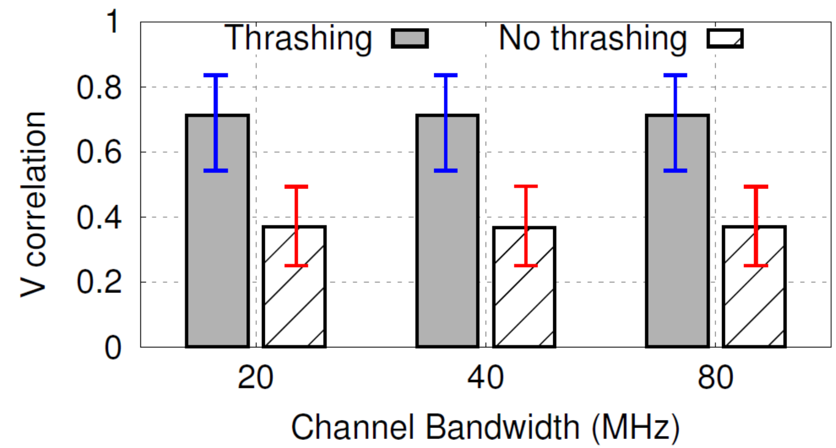

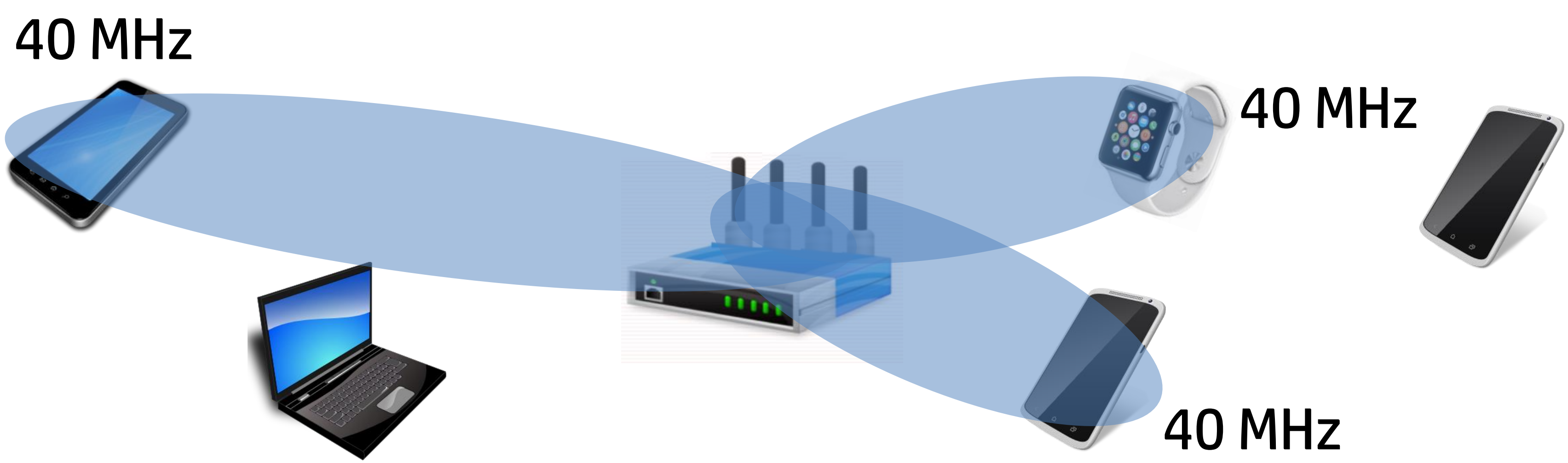

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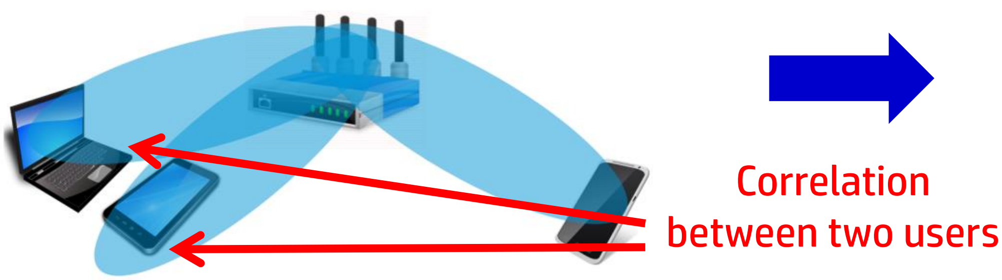
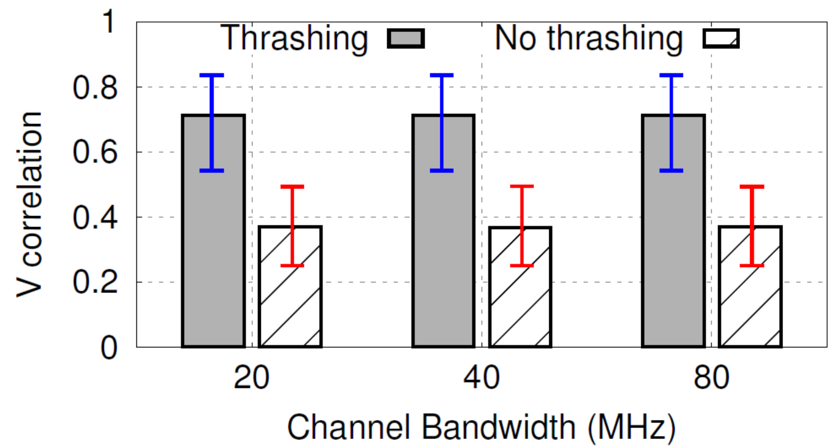
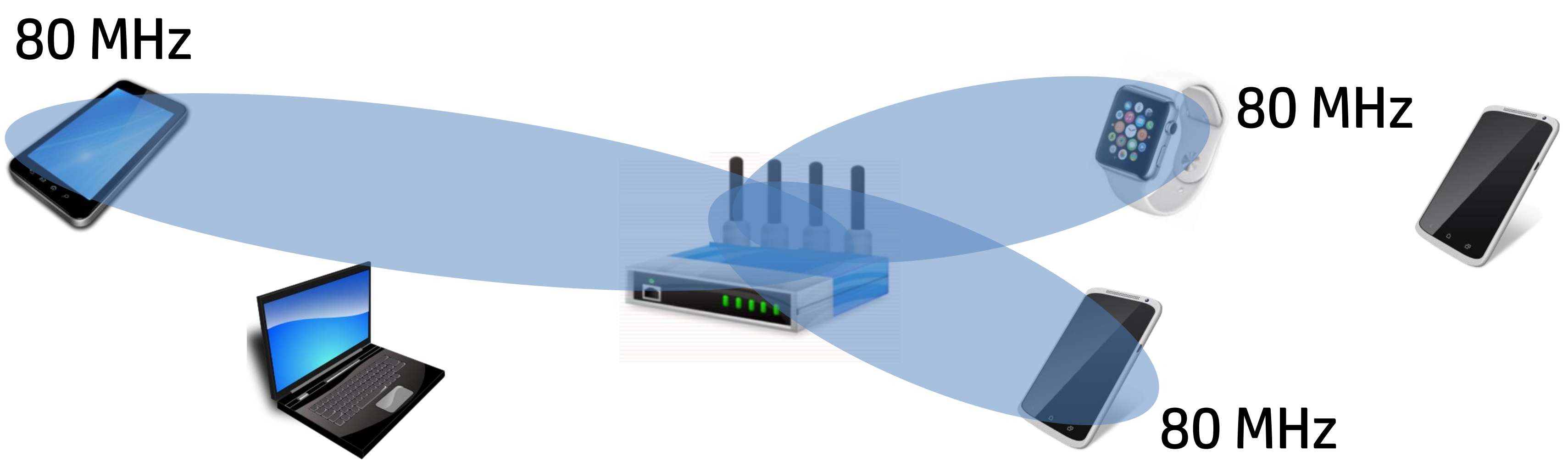
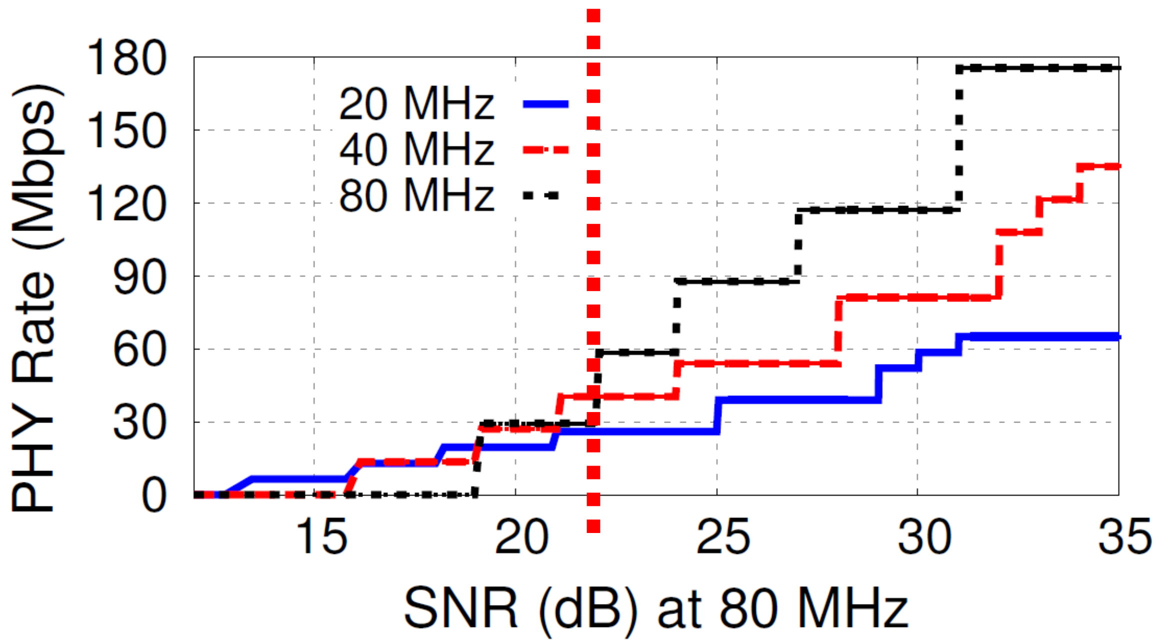






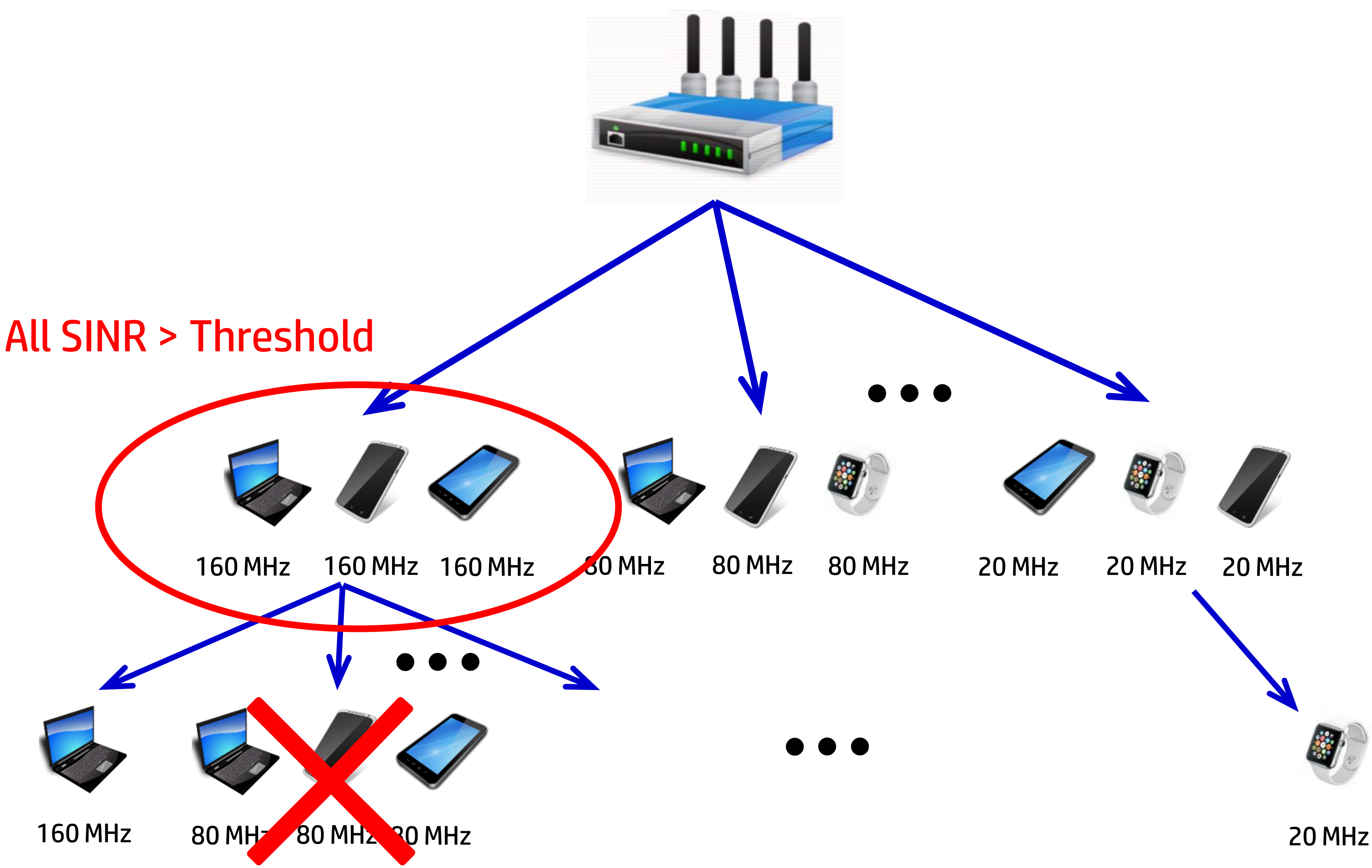
Fast Configuration Selection

- *Strict rate increase* for higher channel bandwidth beyond deterministic signal strength

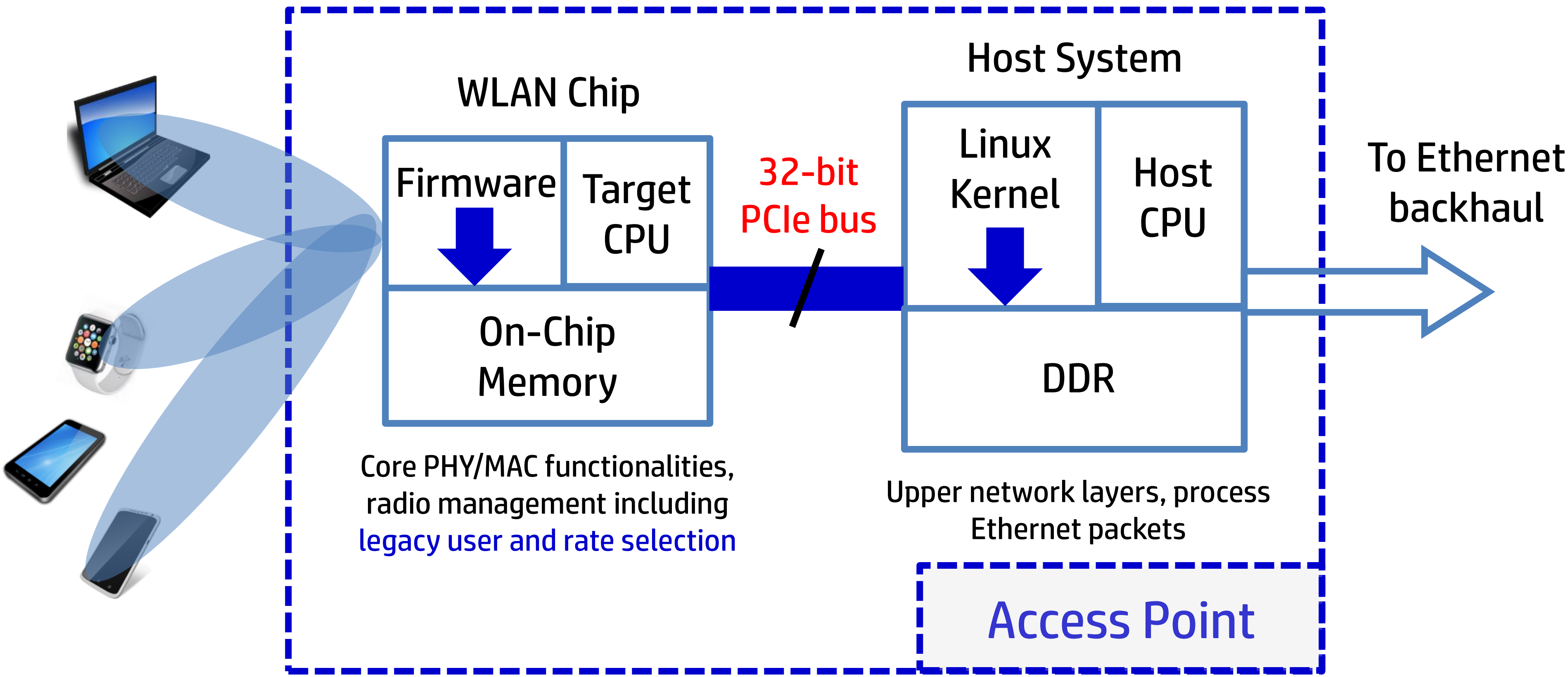


80 MHz PHY rate > 40 MHz PHY rate beyond 22 dB

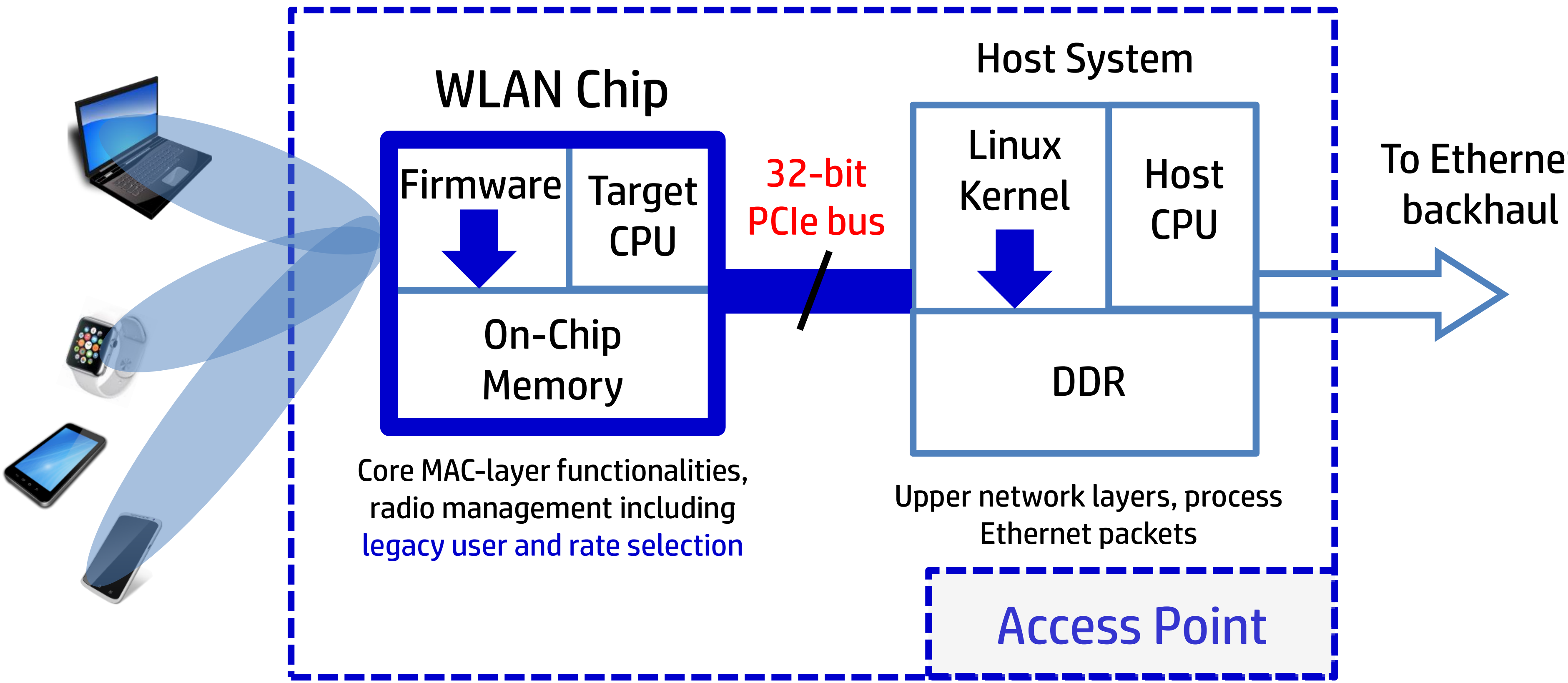
Fast Configuration Selection



Practical Implementation Challenge



Practical Implementation Challenge



- WLAN chip has only 1 MB on-chip memory and a 350 MHz CPU
  - Approximately 98% memory is used by existing functionalities

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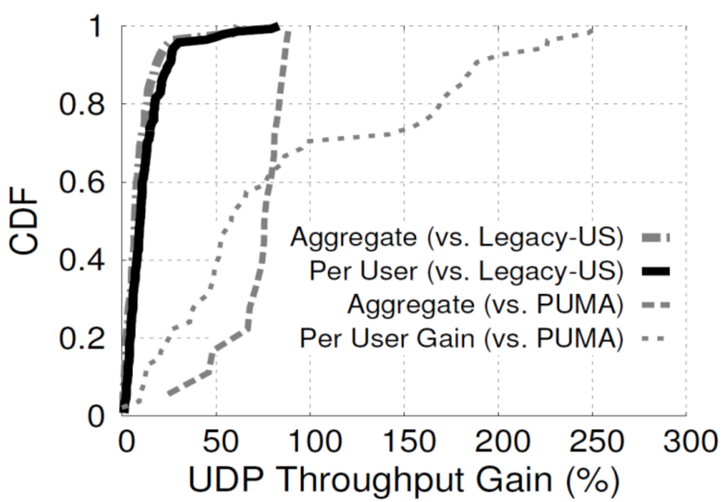
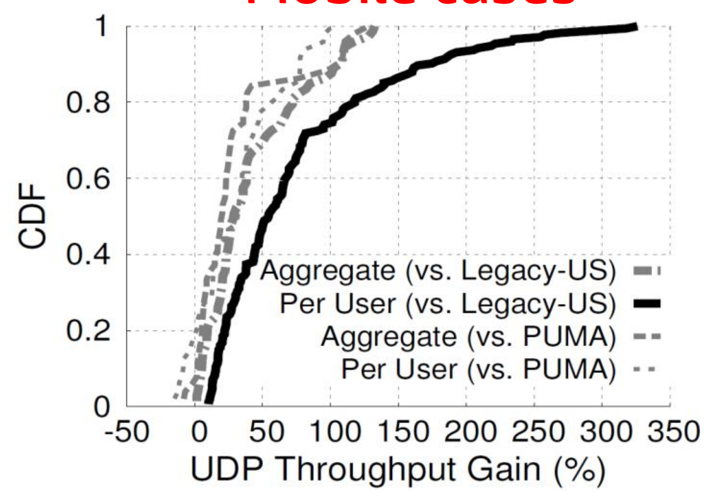
Experimental Evaluation

- We compare MUSE with Legacy-US and existing solution PUMA*
  - PUMA uses a SINR metric where *interference between users are fixed*
- UDP saturated traffics in static and dynamic settings

Static cases



Mobile cases



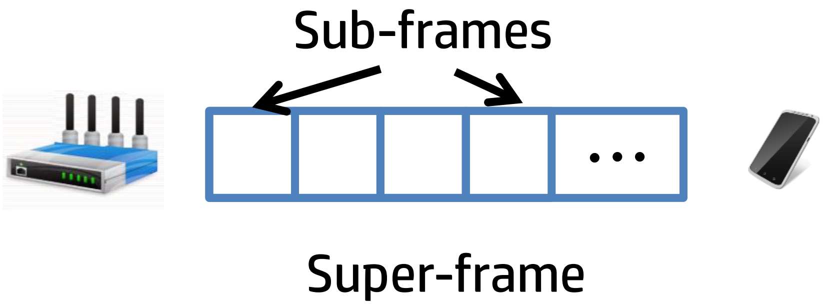
Per-user median gain > 70%

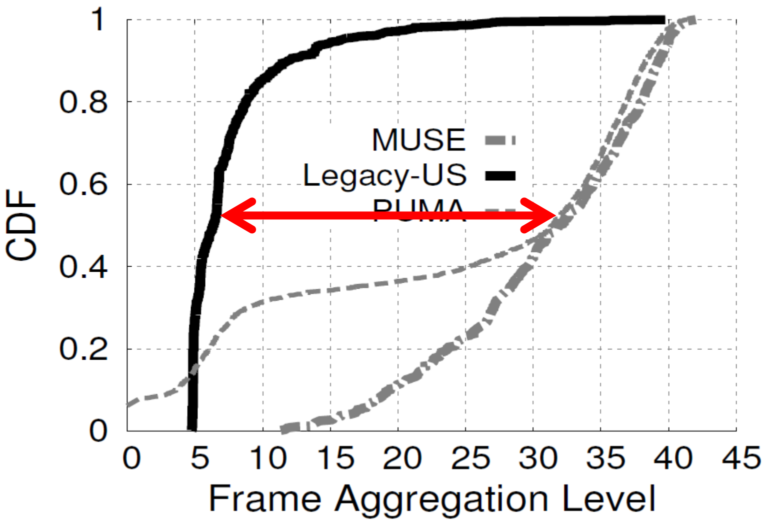
Median performance gain ~50%, with up to 4x per-user gain!

* Mode and User Selection for Multi-User MIMO WLANs without CSI, N. Anand et. al., INFOCOM'15

Analysis of MUSE in High-Gain Scenario

- *Side-benefit* of MUSE from correct user and rate selection
  - PER reduction implicitly improves *frame aggregation level*

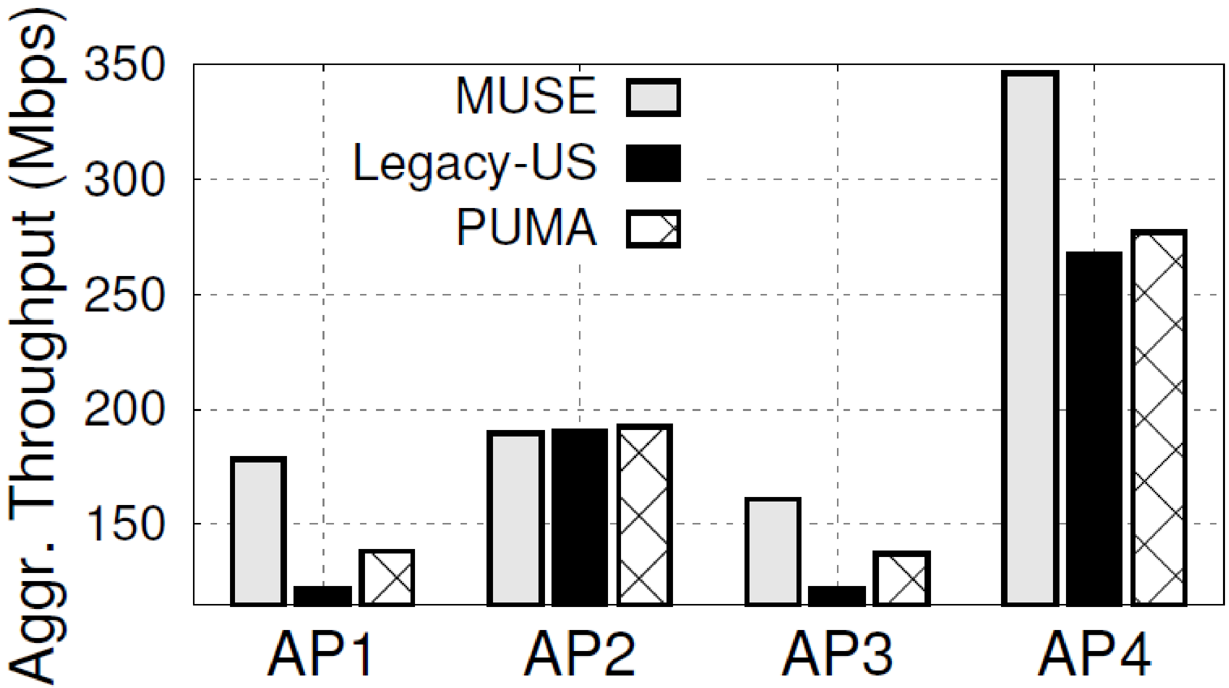




Median frame-aggregation level improves by 4.5x!

Field-Trial of MUSE

- Realistic *field-trial* with 4 APs placed in an enterprise setting
  - 15 smartphones connected to the AP, uncontrolled environmental activities, interference from external access points



Aggregate throughput gain of 30-45% and 20-30% compared to Legacy-US and PUMA. Per-user throughput gain can be up to 3x!

Summary

- Commodity APs avoid state-of-the-art solutions and rely on *suboptimal statistics* that lead to poor MU-MIMO performance

- MUSE leverages existing *low-layer feedback* to design and implement a practical user and rate selection solution

- Our work is the first to *optimize* MU-MIMO performance on 802.11ac commodity access points