USC Viterbi
School of Engineering
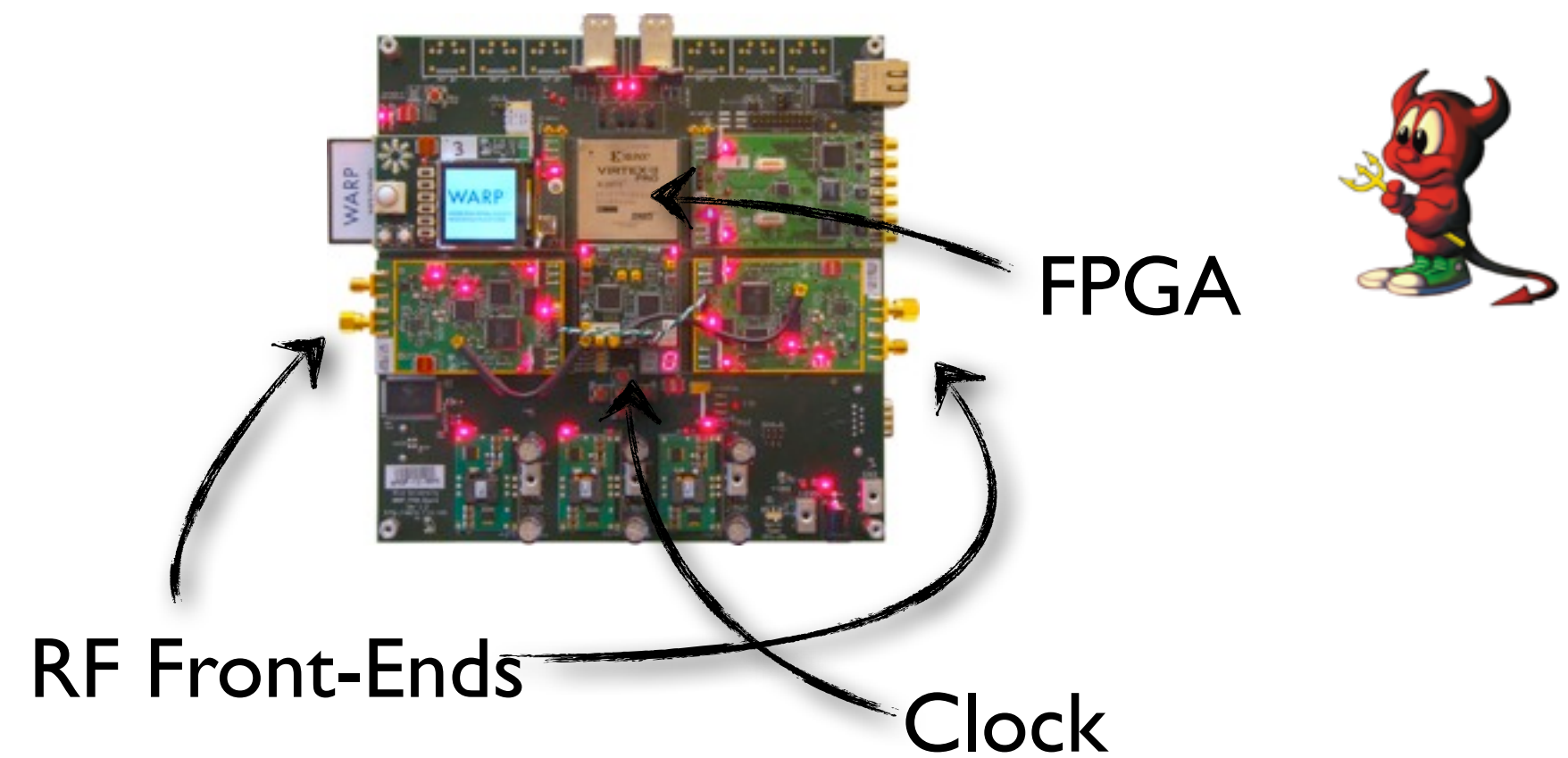
Ming Hsieh Department
of Electrical Engineering

Distributed Multiuser MIMO with Full Spatial Multiplexing

Horia Vlad Balan, Ryan Rogalin, Antonios Michaloliakos, Konstantinos Psounis, Giuseppe Caire
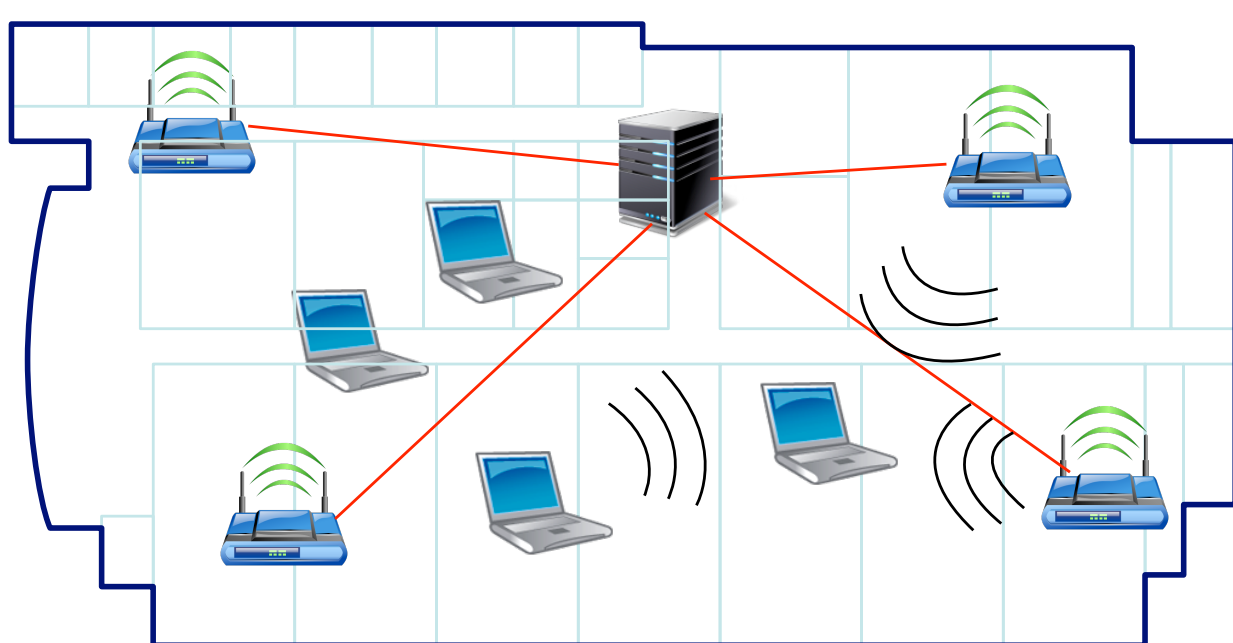
Motivation & Introduction

Multiuser MIMO is leaving the theoretical stage and moving towards practical deployment. Current implementations are limited to single access points, since synchronizing symbol timing and phases across different access points has been traditionally seen as too difficult. Here we present the first practical system realization that disproves this idea. We have managed to synchronize different access points within picoseconds in order to provide phase consistency across different transmitters. Using the resulting increase in spatial diversity, we transmit to multiple users with full spatial multiplexing, obtaining large pre-log capacity gains.

Software Radio
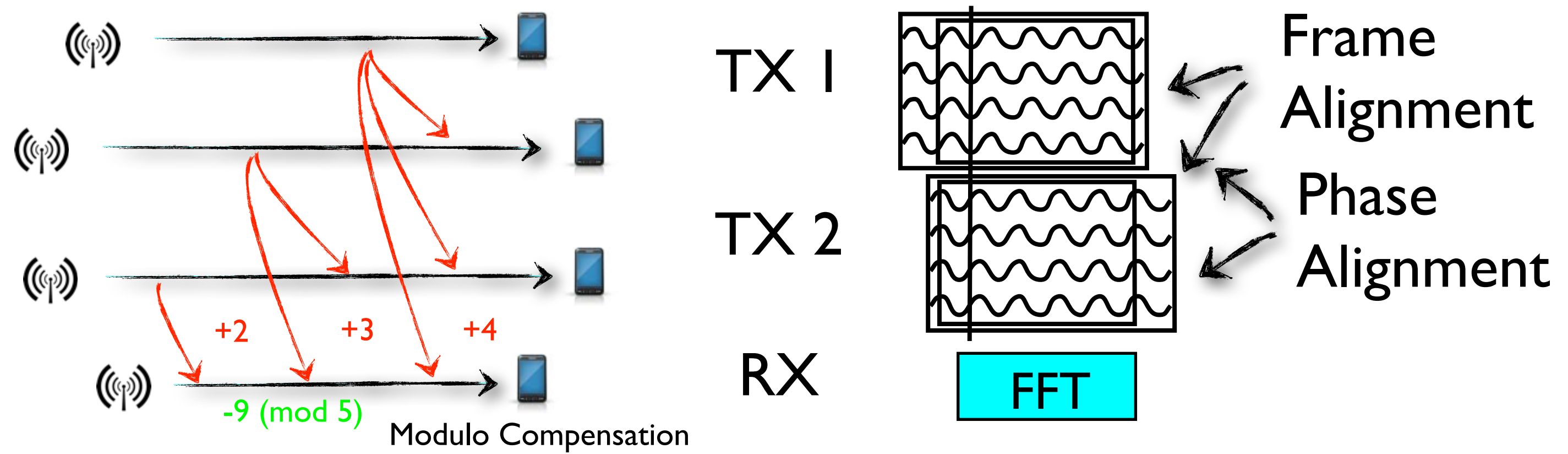
FPGA

RF Front-Ends

Clock

Enterprise WIFI
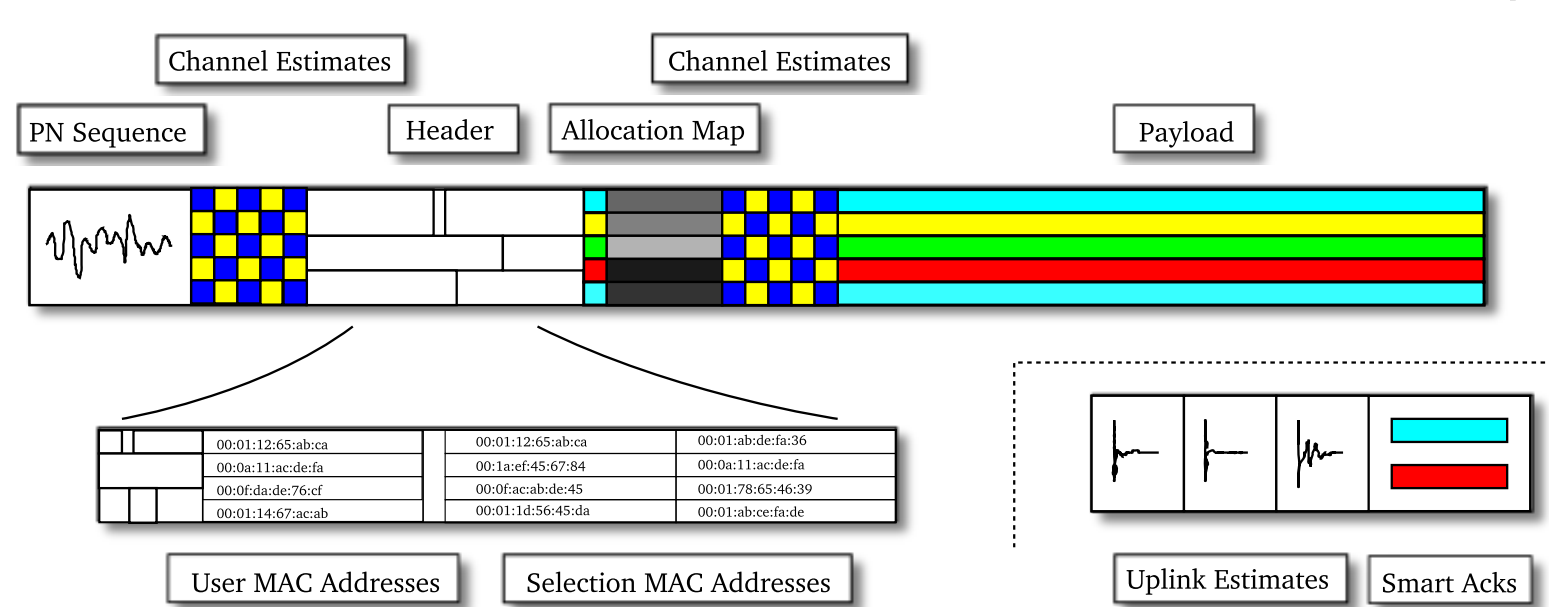
Multiple synchronized access points are controlled by a single server. We would like to achieve a full multiplexing gain in the downlink.

Channel Estimates   Channel Estimates

PN Sequence | Header | Allocation Map | Payload

00:01:12:65:ab:ca	00:01:12:65:ab:ca	00:01:ab:de:5e:36
00:0a:12:ac:de:fa	00:1a:ad:45:67:84	00:06:11:ac:de:fa
00:0f:de:dc:78:cf	00:0f:ac:ab:de:45	00:01:78:65:46:39
00:01:34:67:ac:ab	00:01:14:56:45:da	00:01:ab:ce:fa:de

User MAC Addresses   Selection MAC Addresses

Uplink Estimates | Smart Acks

The MAC layer includes a synchronization header, uplink pilots for estimation and low-overhead acknowledgments.

Distributed MIMO

+2   +3   +4

-9 (mod 5)   Modulo Compensation

TX 1   TX 2   RX
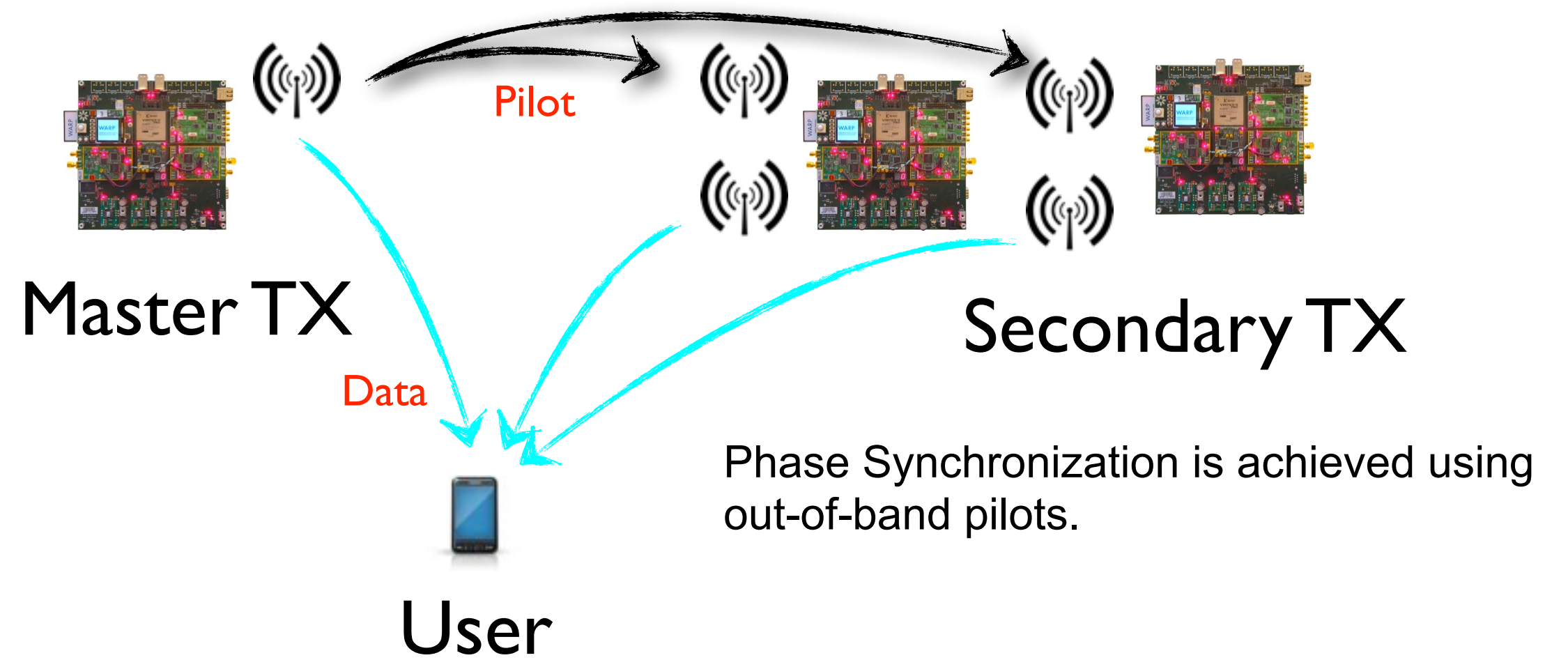
Frame Alignment

Phase Alignment

FFT

The senders precode their data using Tomlinson-Harashima precoding, creating a separate channel for each user.
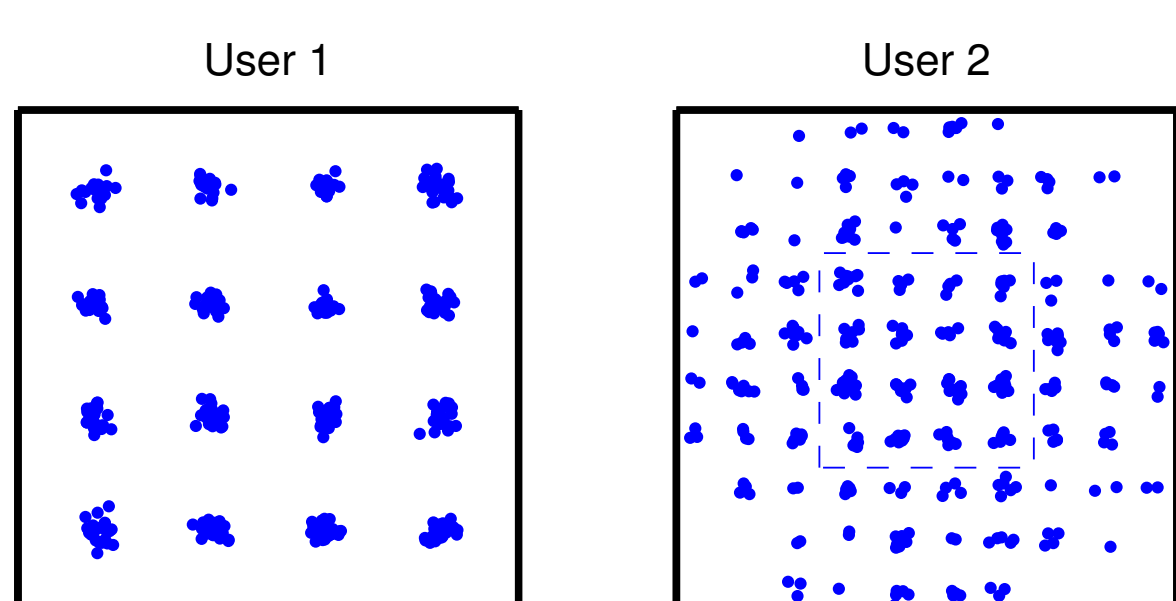
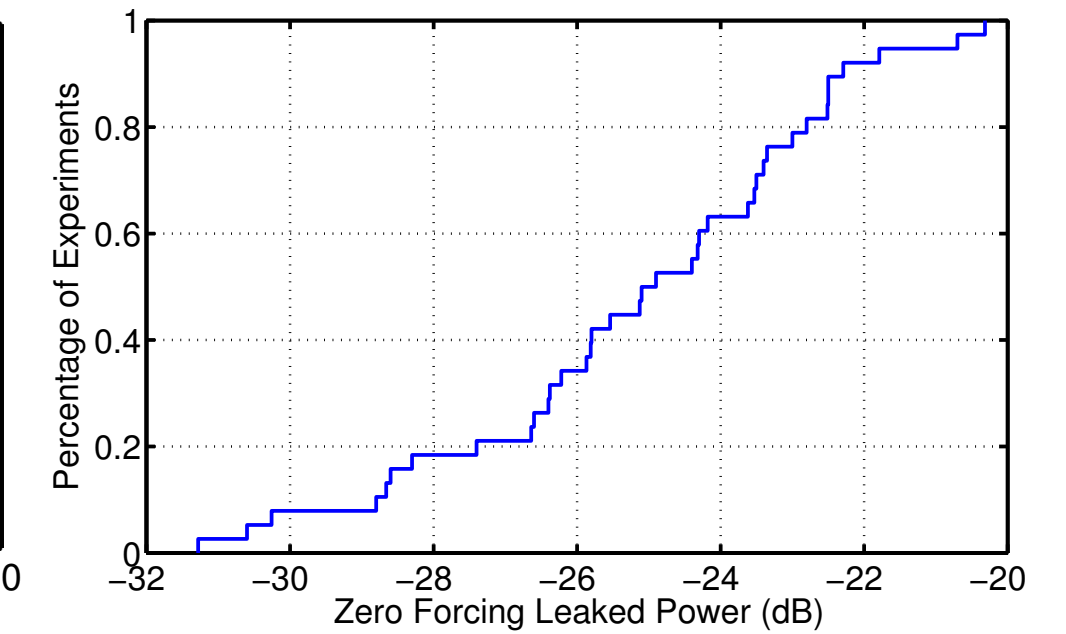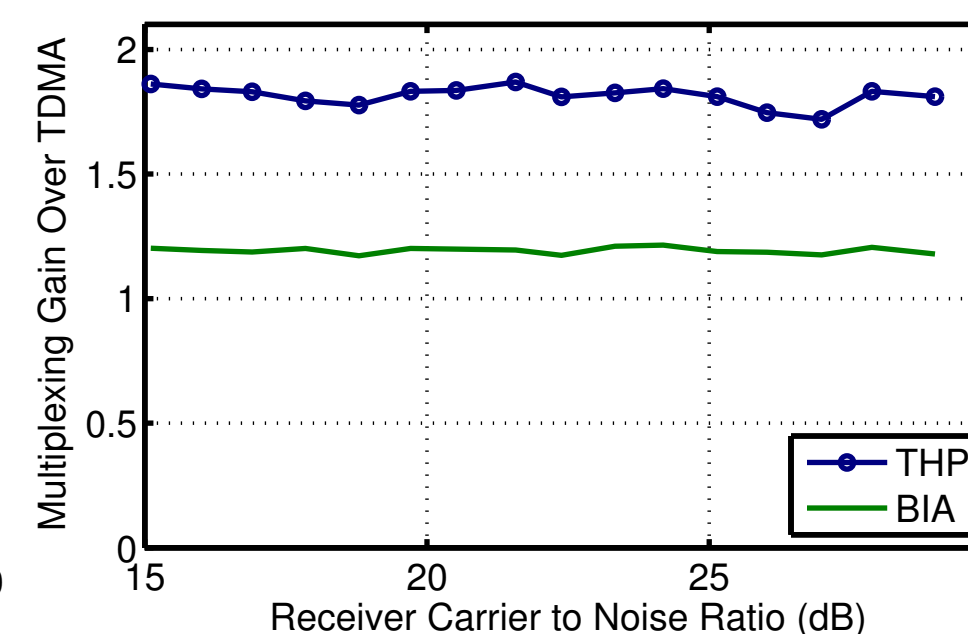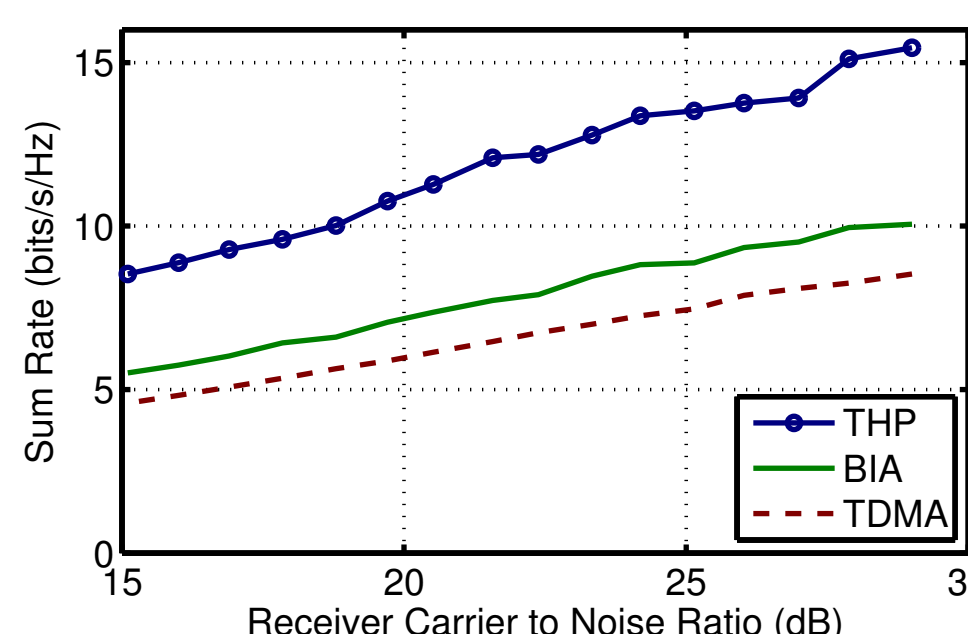The access points synchronize their OFDM symbols within a cyclic prefix interval and synchronize their phases.

Pilot

Master TX   Secondary TX

Data

User

Phase Synchronization is achieved using out-of-band pilots.

Results

User 1   User 2

Each user receives an independent stream of data.

Sum Rate (bits/s/Hz)
Receiver Carrier to Noise Ratio (dB)
THP / BIA / TDMA

Multiplexing Gain Over TDMA
Receiver Carrier to Noise Ratio (dB)
THP / BIA

Percentage of Experiments
Zero Forcing Leaked Power (dB)

For the same level of transmit power, in a 2x2 scenario we observe an 85% multiplexing gain. The channel separation is better than 22 dB.

See our Demo as well!!!

Ming Hsieh Institute
Ming Hsieh Department of Electrical Engineering

USC Viterbi
School of Engineering
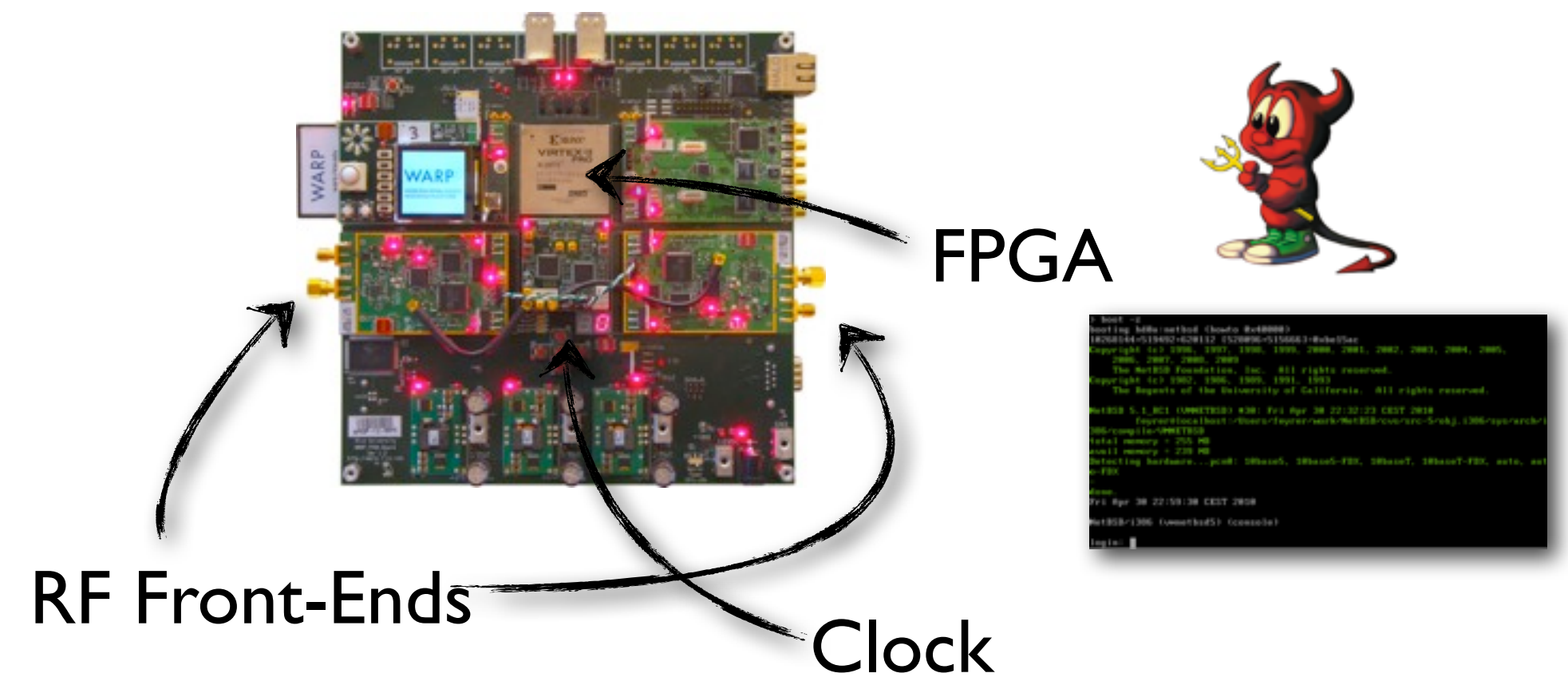
Ming Hsieh Department of Electrical Engineering

Distributed Multiuser MIMO with Full Spatial Multiplexing

Horia Vlad Balan, Ryan Rogalin, Antonios Michaloliakos, Konstantinos Psounis, Giuseppe Caire
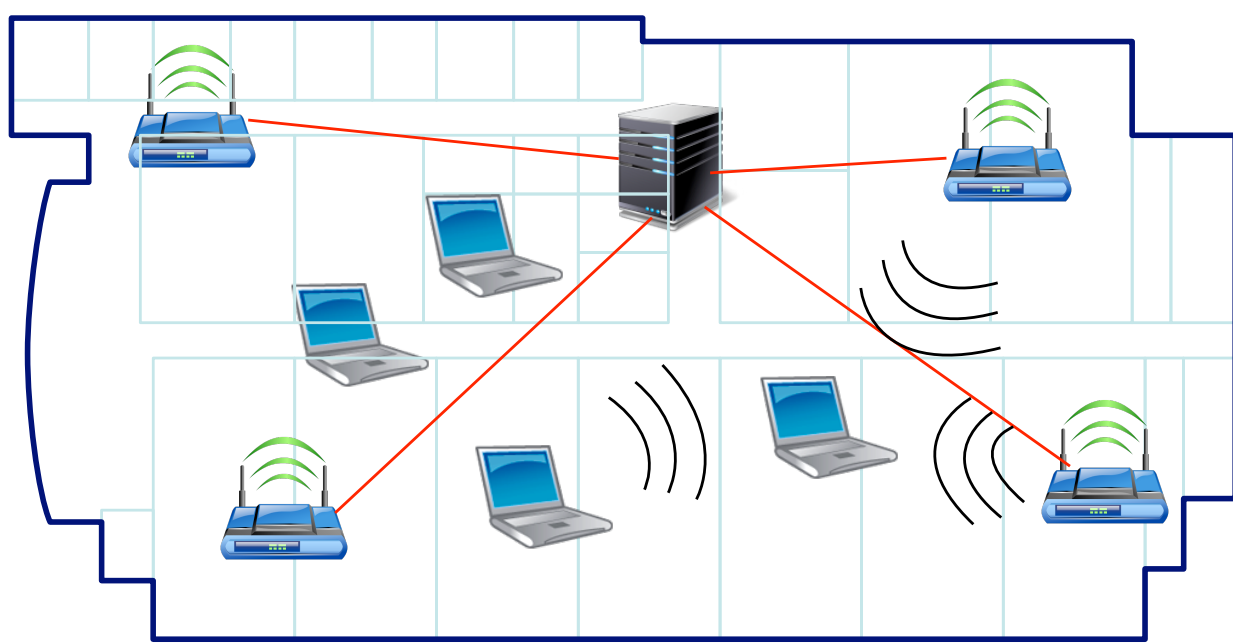
Motivation & Introduction

Multiuser MIMO is leaving the theoretical stage and moving towards practical deployment. Current implementations are limited to single access points, since synchronizing symbol timing and phases across different access points has been traditionally seen as too difficult. Here we present the first practical system realization that disproves this idea. We have managed to synchronize different access points within picoseconds in order to provide phase consistency across different transmitters. Using the resulting increase in spatial diversity, we transmit to multiple users with full spatial multiplexing, obtaining large pre-log capacity gains.
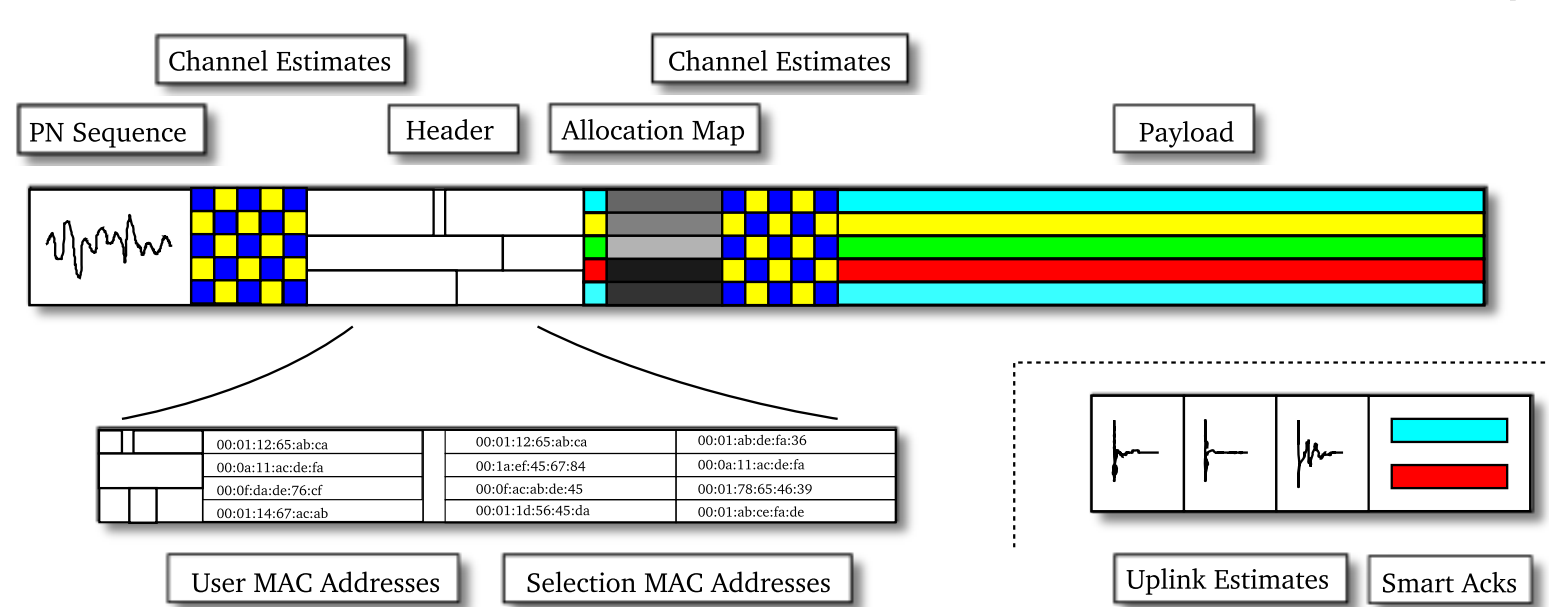
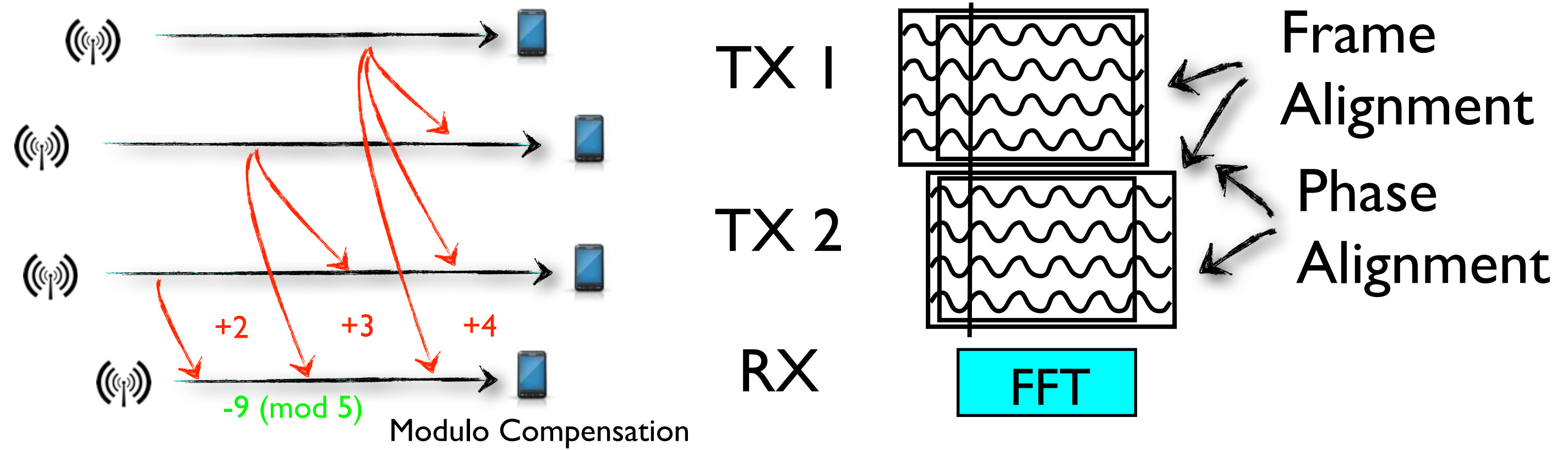## Software Radio

FPGA

RF Front-Ends

Clock

Enterprise WIFI

Multiple synchronized access points are controlled by a single server. We would like to achieve a full multiplexing gain in the downlink.
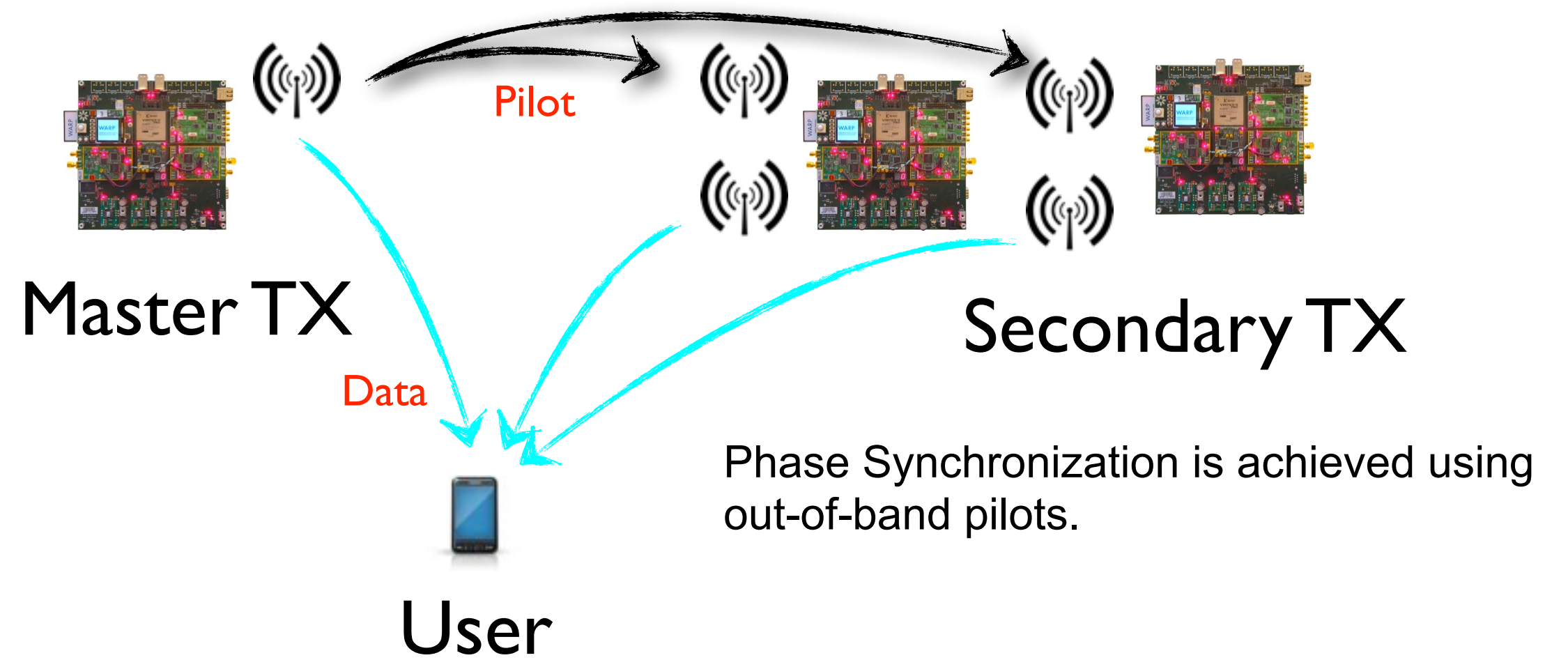

Channel Estimates   Channel Estimates
PN Sequence   Header   Allocation Map   Payload

User MAC Addresses   Selection MAC Addresses   Uplink Estimates   Smart Acks

The MAC layer includes a synchronization header, uplink pilots for estimation and low-overhead acknowledgments.

Distributed MIMO

+2   +3   +4
-9 (mod 5)
Modulo Compensation

TX 1
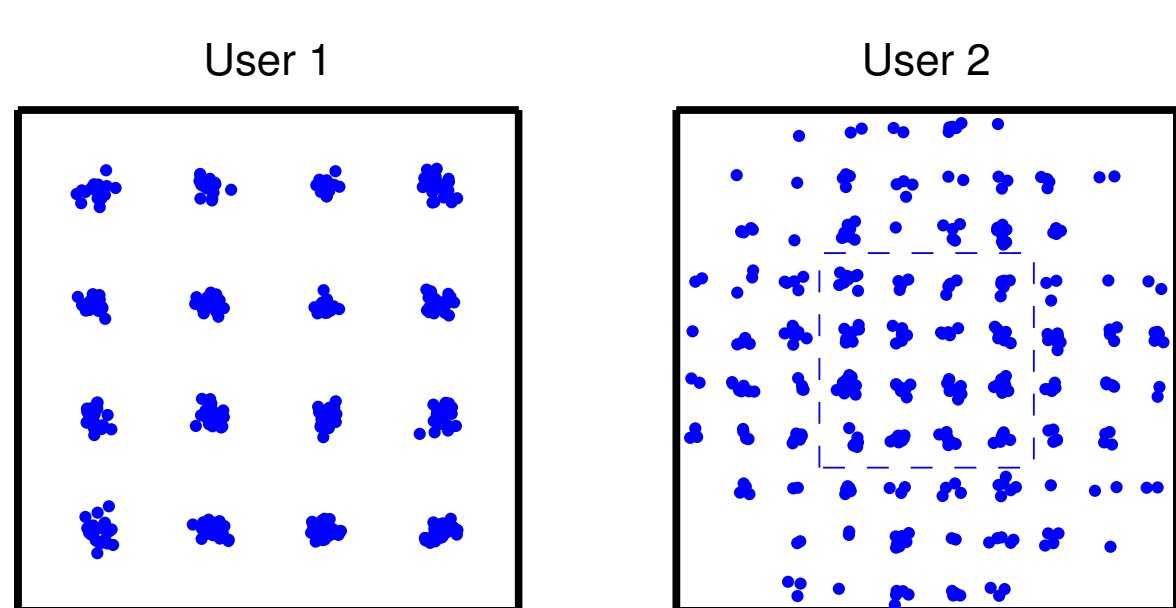TX 2
RX
FFT

Frame Alignment
Phase Alignment

The senders precode their data using Tomlinson-Harashima precoding, creating a separate channel for each user.

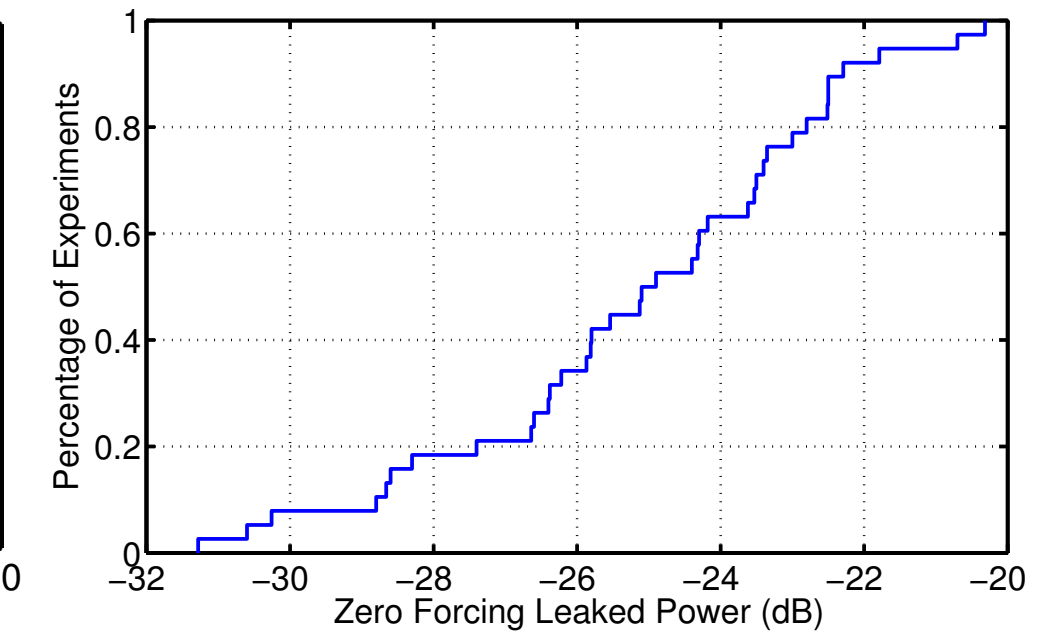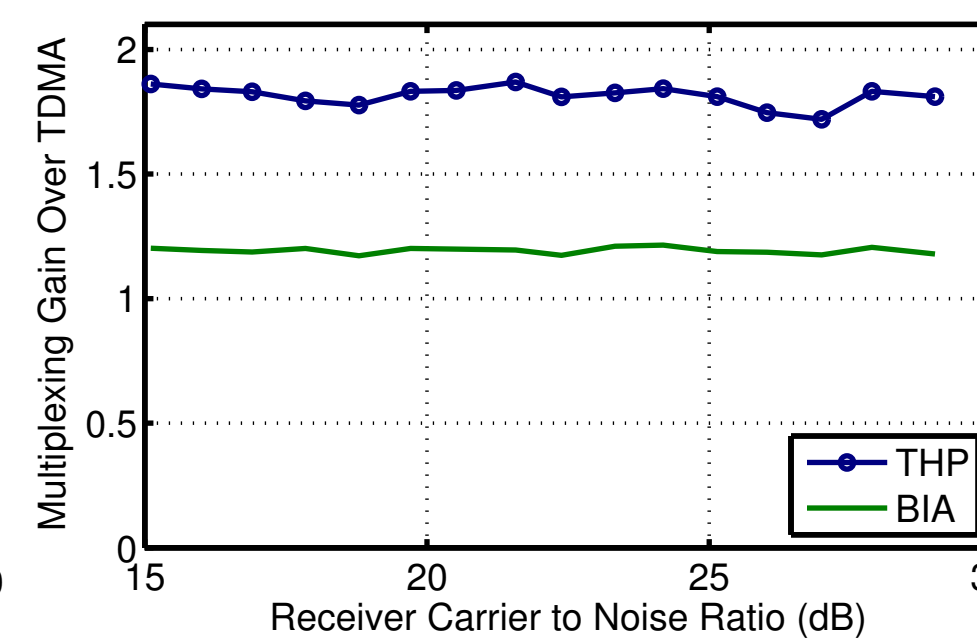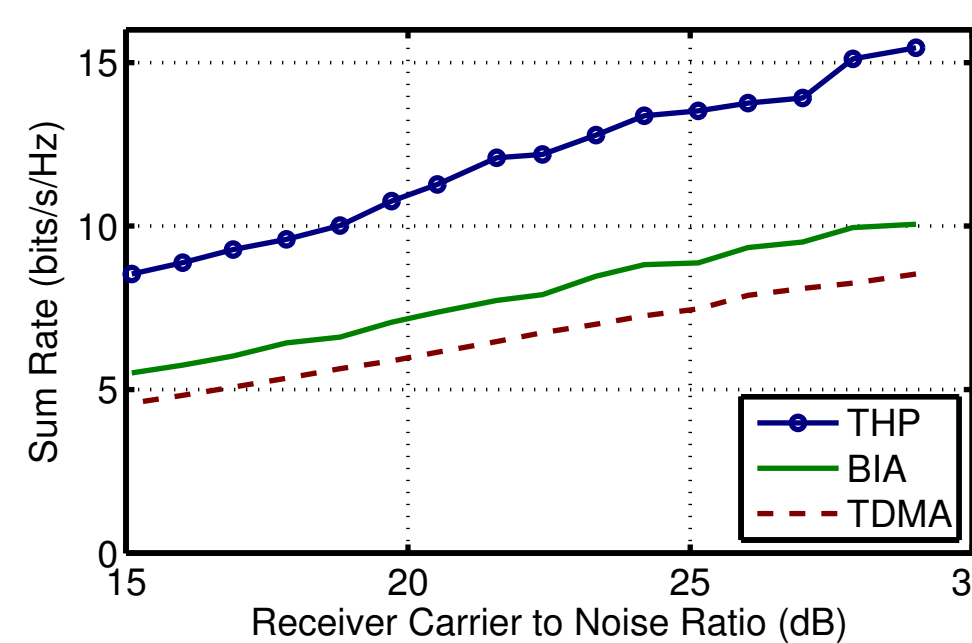The access points synchronize their OFDM symbols within a cyclic prefix interval and synchronize their phases.

Pilot

Master TX

Secondary TX

Data

User

Phase Synchronization is achieved using out-of-band pilots.

Results

User 1   User 2

Each user receives an independent stream of data.

For the same level of transmit power, in a 2x2 scenario we observe an 85% multiplexing gain. The channel separation is better than 22 dB.

See our Demo as well!!!

Ming Hsieh Institute
Ming Hsieh Department of Electrical Engineering