Design and Deployment Considerations for High Performance MIMO Testbeds

Konstantinos Pelechrinis*, Ioannis Broustis†, Theodoros Salonidis ⋆, Srikanth V. Krisnamurthy*, Prasant Mohapatra ‡

*University of California, Riverside, †University of Thessaly, ⋆Thomson Research, Paris, ‡University of California, Davis

November 18, 2008

Problem Motivation

- Multiple Input Multiple Output (MIMO) systems have gained a lot of attention.
  - Higher transmission rates
  - Higher reliability
- PHY layer gains have been shown to be viable.
- What is the real "networked" performance of MIMO?
- What are the gains observed in higher layers?
  - Isolated links
  - Competing link
- Lack of experimental studies.
- Correct testbed design and deployement should account for:
  - Reliable results
  - Affordable cost
  - Manageability
  - Extendability
  - Re-usability

Our Work in a Nutshell

- Experimental characterization of MIMO links.
  - Indoor experiments with strong platform (benchmark results).
  - Quantify 802.11n performance:
    - Isolated links, competing links, usage of channel bonding
  - Metrics of interest: application throughput, Packet Delivery Ratio (PDR), node degree and energy savings.
- Candidate platforms for deploying a MIMO testbed.
  - Embedded computers (e.g. Soekris boxes), desktop PCs.
- Repeat the experiments with every candidate platform.
- Compare results with benchmarks.
- Discuss and decide on the platform that meets our criteria for a MIMO testbed deployment.

Roadmap

- Problem motivation
- Our work in a nutshell
- MIMO background
- 802.11n (benchmark) performance
- Candidate platforms - experiments
- Conclusions

MIMO Background (1/2)

- PHY layer technology that utilizes multiple antenna elements.
- 2 different modes of operation
  - SDM (Spatial Division Multiplexing)
    - Each antenna transmits an independent data stream.
    - Higher throughputs are possible (up to 300Mbps).
    - Realibility similar to single antenna communications (SISO).
  - STBC (Space Time Block Coding)
    - Fading characteristics among antenna pairs are independent (spatial diversity).
    - Correlated blocks of the data are transmitted from the antennae at separate times (temporal diversity).
    - **Alamouti Codes** are one example of STBC codes. For 2x2 MIMO systems the corresponding matrix is:

$$S_2 = \begin{pmatrix} s_0 & s_1 \\ -s_1^* & s_0^* \end{pmatrix}$$

MIMO Background (2/2)

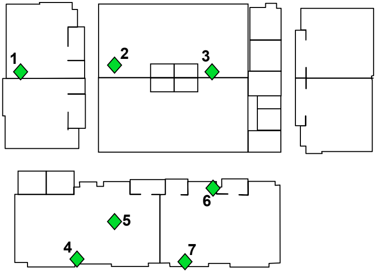
- 802.11n is the MAC protocol for MIMO communications.
- CSMA/CA is the access policy.
- Both SDM and STBC modes are supported.
- Basic features of 802.11n include:
  - Block Acknowledgment
    - Many data packets are getting acknowledged with a single-block ACK.
  - Channel Bonding
    - A wider channel of $40MHz$ can be used, in order to achieve higher rates.
  - Frame Aggregation
    - Multiple data frames can be send into a larger frame with one medium access.

Roadmap

- Problem motivation
- Our work in a nutshell
- MIMO background
- 802.11n (benchmark) performance
- Candidate platforms - experiments
- Conclusions

802.11n (benchmark) performance (1/5)

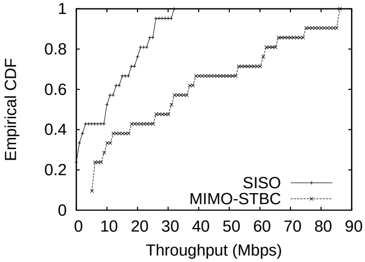
- We perform extensive measurements utilizing a powerful platform.
  - 7 desktop PCs with 2.5GHz dual-core CPU, 1GB RAM, Ralink RT2860 wireless NICs and 5-dBi omni antennae.
  - Indoor setting, STBC mode of operation, link performance in isolation and under contention.

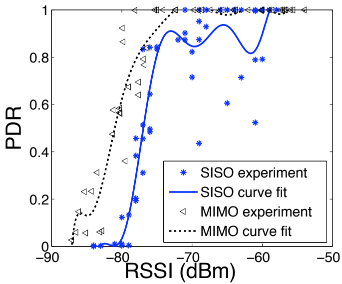


802.11n (benchmark) performance (2/5)

MIMO in isolated settings

Main performance metrics: application throughput, PDR, network connectivity and T_x power savings.

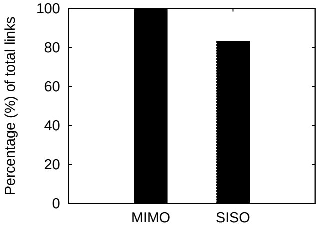


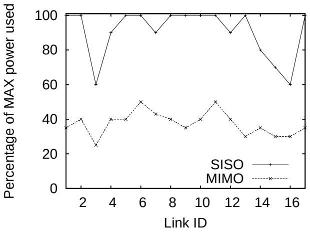


- MIMO can achieve much higher throughput than the corresponding SISO.
- For a fixed RSSI, PDR is higher with MIMO (and more stable).

802.11n (benchmark) performance (3/5)

MIMO in isolated settings

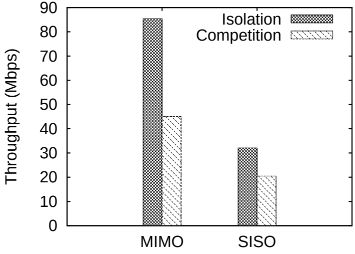


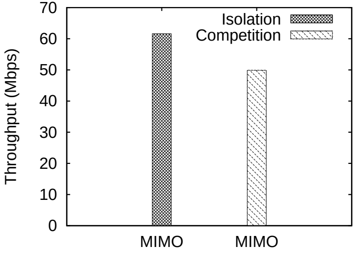


- For the same node layout the number of feasible links with MIMO is much higher than with SISO (19% larger).
- The transmission power required for MIMO in order to achieve the same throughput as with SISO is much lower (about 50%-70% lower).

802.11n (benchmark) performance (4/5)

MIMO under multi-user settings



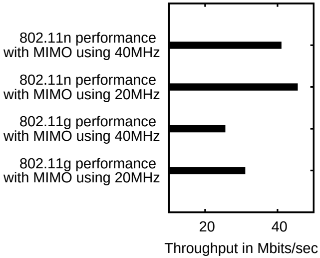


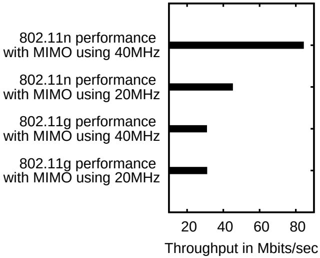
- Competition with a reliable SISO link degrades the performance by approximately 55%.
- Competition among MIMO links leads to smallers hits (approximately 20% degradation).
- 802.11n does not exploit the PHY layer attributes of MIMO to allow multiple, successful, concurrent transmissions.

802.11n (benchmark) performance (5/5)

MIMO under multi-user settings

- Channel bonding utilizies 40MHz channel.
  - Increased transmission rate for isolated links.
  - Increased levels of intereference for multi-user settings.





- Channel bonding increases the level of intereference on adjacent channels.
- Non - adjacent channels are not being affected from the use of channel donding.

Roadmap

- Problem motivation
- Our work in a nutshell
- MIMO background
- 802.11n (benchmark) performance
- Candidate platforms - experiments
- Conclusions

Candidate platforms - experiments (1/2)

- We experimented with 3 different platforms:
  - **Soekris net4826**: 266MHz i586 processor, 128MB SDRAM and two mini-PCI slots.
  - **Soekris net5501**: 500MHz CPU, 512MB DDR-SDRAM, one mini-PCI slot and one PCI slot.
  - **Dell 530S desktop**: 2.5GHz dual-core Intel processor and 1GB RAM (benchmark platform).
- Throughput experiments with 3 modes: SISO, MIMO STBC (20MHz), MIMO SDM (20MHz).

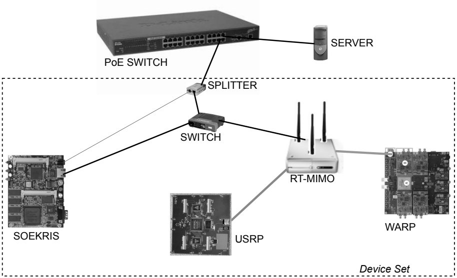
	SISO	STBC	SDM
net4826	19.3	33.4	34.1
net5501	23.4	44.2	60.4
Dell	24.1	45.4	62.1

Candidate platforms - experiments (1/2)

- Benefits of channel bonding with various platforms.

	SISO	STBC 20	STBC 40	SDM 20	SDM 40
net4826	19.3	33.4	33.5	34.1	33.1
net5501	23.4	44.2	83.7	60.4	118.6
Dell	24.1	45.4	85.9	62.1	121.2

- Connectivity and energy savings do not vary with the platform used.
- Both Soekris net5501 and Dell 530S can exploit MIMO potentials.
- For re-usability purposes we choose Dell desktops.



Roadmap

- Problem motivation
- Our work in a nutshell
- MIMO background
- 802.11n (benchmark) performance
- Candidate platforms - experiments
- Conclusions

Conclusions

- Experimental study of MIMO systems from a network perspective.
- MIMO provides significant benefits on isolated links.
  - Higher throughput, higher PDR, better connectivity and possible energy savings.
- 802.11n does not exploit the PHY layer properties of MIMO at a mutli-user setting.
- Channel bonding in conjuction with 802.11n can significanlty degrade the performance.
- Devices with small processing capabilities cannot be used for MIMO experimental studies.

Thank you!
Questions?