On link rate adaptation in 802.11n WLANs

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Introduction

- 802.11n
  - Latest very high throughput WLAN standard
  - Improved performance and new features compared to 802.11a/b/g
- Link rate adaptation
  - Important for performance
  - Deployable strategies that do not require fine-grained PHY statistics desirable
- This work: Link rate adaptation for 802.11n links without PHY statistics

Link Rate Adaptation Background

- Goal
  - Modify transmit rate to maintain desired Bit Error Rate across different link conditions

- Traditional solutions (802.11 a/b/g)
  - Adapting modulation coding scheme (MCS)
  - Based on statistics such as SINR , packet loss, delivery ratio, throughput, etc

SINR Range (dB)	Rate	SINR Range (dB)	Rate
≥ 24.56	54	[10.79,17.04)	18
[24.05,24.56)	48	[9.03,10.79)	12
[18.8,24.05)	36	[7.78,9.03)	9
[17.04,18.8)	24	[6.02,7.78)	6

802.11n Background

- Multiple Input Multiple Output
  - Independent data transmitted on each Tx antenna decoded with Rx processing (on same channel)
  - Each stream has different gain
  - Rate of k-stream MIMO = k *Rate of 1-stream SISO provided channel rank is full (uncorrelated)

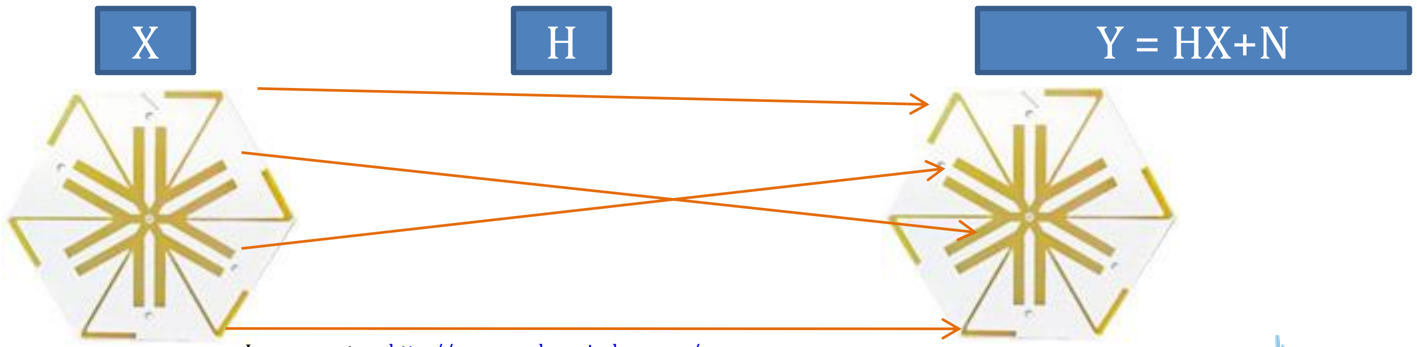


Image courtesy http://www.ruckuswireless.com/

Outline

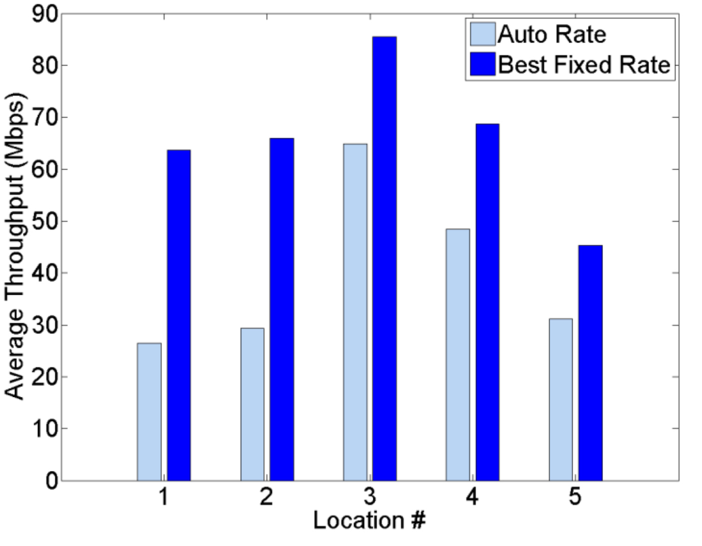
- How well do current 802.11n interfaces perform?
- What are the underlying reasons?
- What are good approaches for MIMO rate adaptation?

Practical 802.11n Performance

- Experimental setup
  - Linksys WRT600N AP and Sparklan (Atheros) client card at 5 locations
  - 5 GHz band (20 MHz channel)
  - Single and two streams
  - Downlink Iperf UDP Traffic
  - Observe:
    - Default auto-rate
    - Best value of manually set fixed-rate

Practical 802.11n Performance

- Large gap between achieved and expected throughput (2.7x)



- Trends similar even for Ralink and Intel cards

Underlying Issues

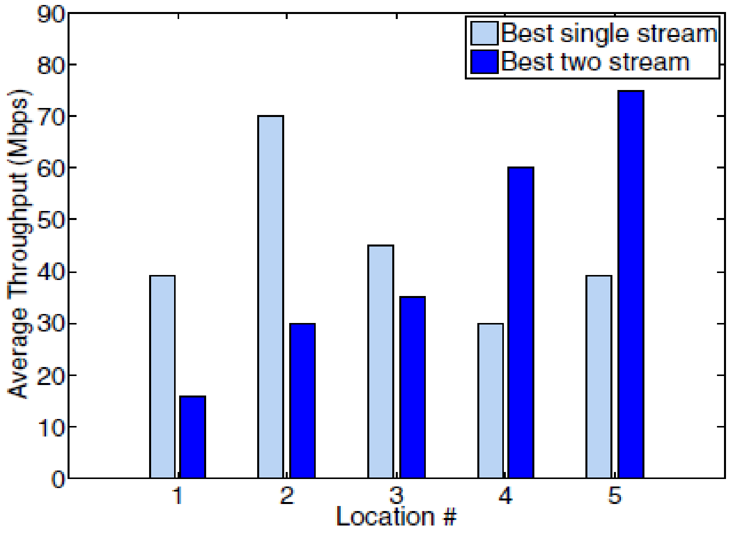
- 802.11n rate adaptation algorithms are typically extensions of 802.11g algorithms
- Issues
  - Linear ordering of MCS is not true for 802.11n
    - For e.g. MCS 1,8
  - Signal powers are not reflective of channel goodness unlike in 802.11a/g
    - Channel matrix H

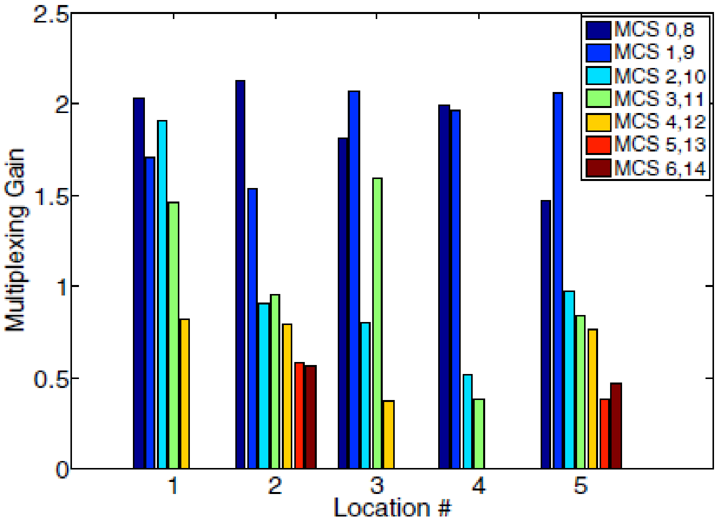
Single Stream		**Two stream**	
MCS	Rate (Mbps)	MCS	Rate (Mbps)
0	6.5	8	13
1	13	9	26
2	19.5	10	39
3	26	11	52
4	39	12	78
5	52	13	104
6	58.5	14	117
7	65	15	130

Stream Selection Problem

- A new degree of freedom: Multiple streams
- Stream selection problem
  - Critical and non-trivial
  - Multiple streams not always better
  - Sustainability of spatial streams for given setting
    - Channel quality (H)
    - Interference effect

I. Channel quality





- Best single stream (MCS 0-7) rate and best two stream rate (MCS 8 -15)
- Two streams not always beneficial
- Mux. Gain

$$G(s,m,c) = \frac{Throughput(s,m,c)}{Throughput(1,m,c)}$$

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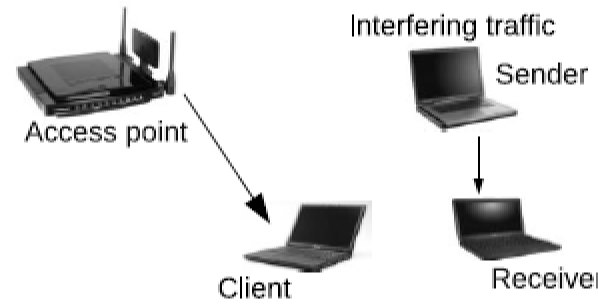
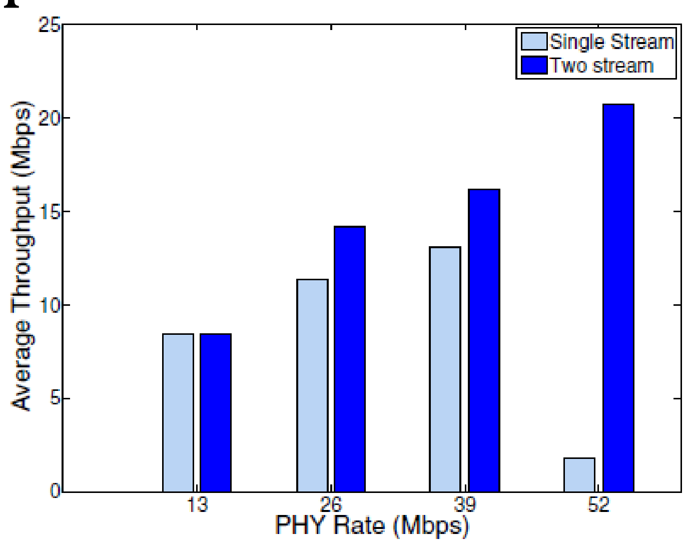
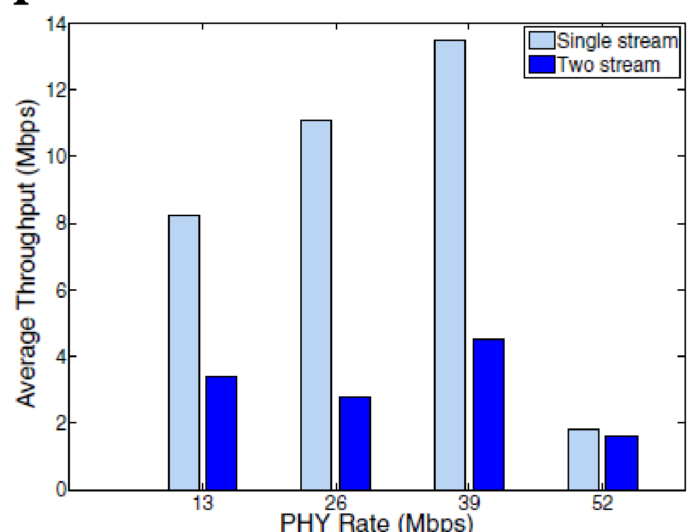
II. Interference effect

- Physical Carrier Sense disabled at the interferer
- Moderate and high power interference
- Impact of interference complex







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Stream Selection Metric

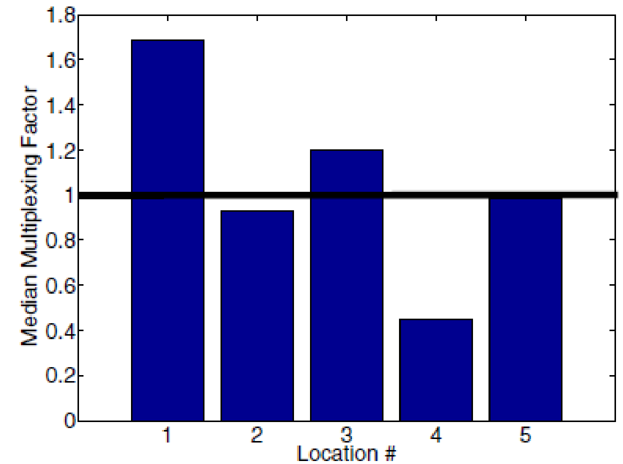
- Trivial approach: Try all possible MCS and pick the best
  - For two streams, 16 possibilities (complex!)
- Median Multiplexing Factor (MMF) Metric
  - Leverages throughput probing with just four probes
  - For s streams

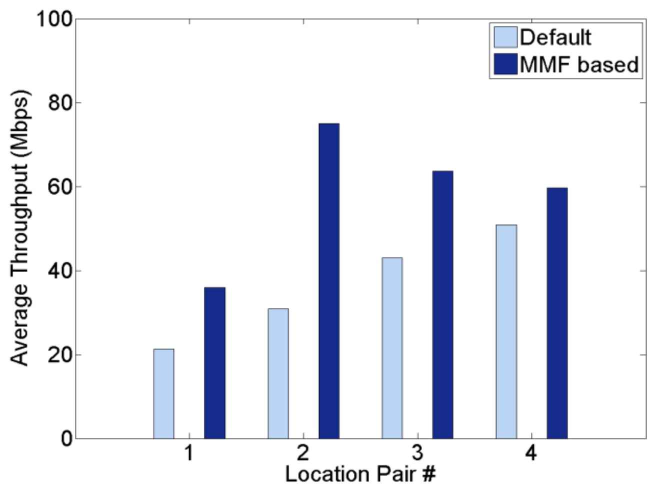
$$MMF(s) = \frac{\frac{Rate(MCS(3+(s-1)8))}{Rate(MCS(3))} + \frac{Rate(MCS(4+(s-1)8))}{Rate(MCS(4))}}{2}$$

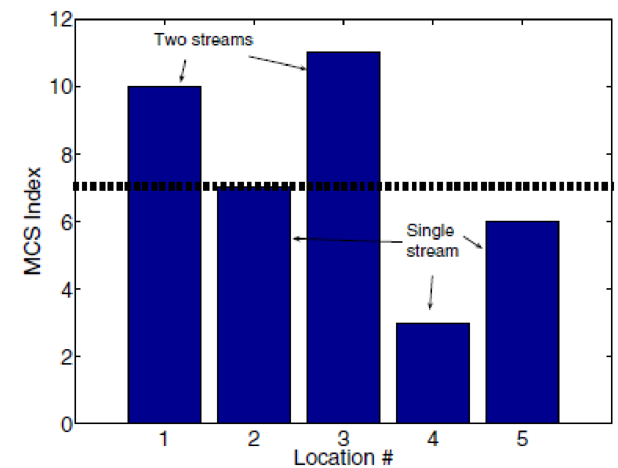
  - Rate is the actual packet delivery rate (bps)
  - MMF value is used to determine optimal MCS index
- For two streams
  - 0 < MMF < 1, one stream is best and the best MCS index is MMF *7
  - 1< MMF <2, two streams are best, with MCS index MMF*7+7

Evaluation of MMF

- Good correlation between the Metric and the correct MCS Index
- Throughput benefits across locations and vendors







Conclusion and Future Work

- Analyzed the performance of current 802.11n rate adaptation using experiments
- Developed a new metric for stream selection
  - Does not require PHY feedback
  - Reduces search complexity
  - Works across manufacturers
- Future Work
  - Evaluation across multiple scenarios

Thank You

Send questions and comments to sriram@ece.gatech.edu