Channel-aware Optimization: A survey

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TÉCNICO LISBOA

Motivation: Perfect World

- Small Home/Office
- Wireless substitutes Wires
- Just Works

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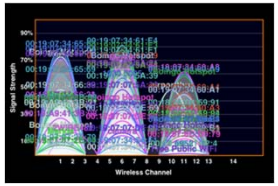
Motivation: Reality

- Dense RF Environments
- Spectrum is Shared
- Mobility is not the best
- Total Capacity is Degraded
- QoS is helps and sometimes required



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Motivation: Limitations

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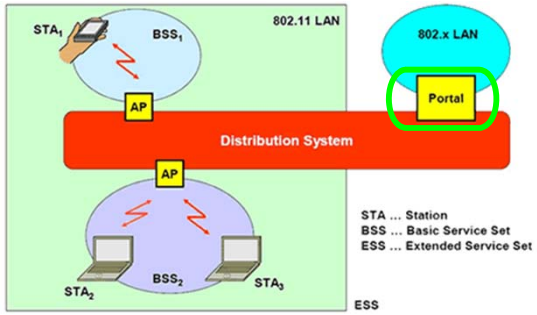
- What part of the system are we allowed to change?



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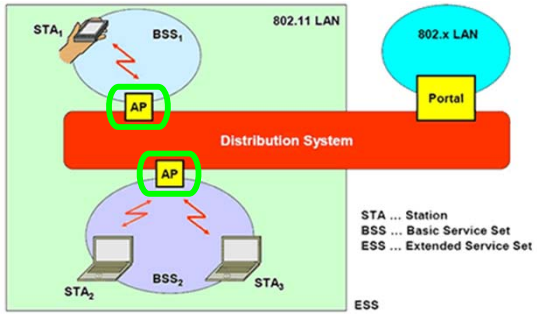

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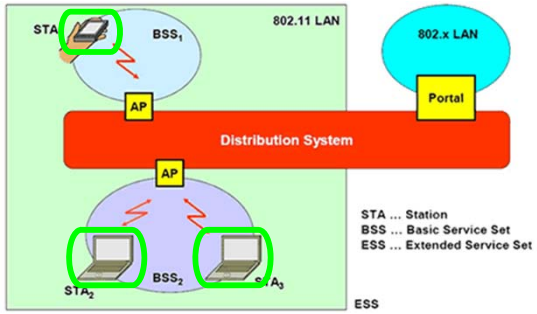

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Motivation: Limitations/Problems

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- ~80% of total Traffic is Downlink (AP->Client)
- Options:
  - ➢ Keep the Clients unmodified (Legacy Support)
  - ➢ Change the Infrastructure (AP, Router, Shaper)
- 802.11 DCF is good but it has two main challenges:
  - ➢ Exposed Terminals (Low Spatial Reuse)
  - ➢ Hidden Terminals
- RTS-CTS solves some Hidden terminal problems but:
  - ➢ Wastes Airtime, Inefficient
  - ➢ Not a Complete Solution

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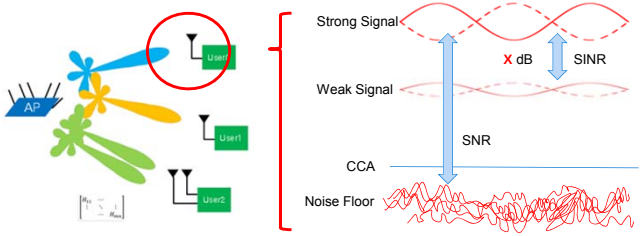
Nomenclature

- SINR - Signal-to-interference-plus-noise ratio
- CCA - Clear Channel Assessment
- Capture Effect
- Directional Phased Array Antenna (MU-MIMO)



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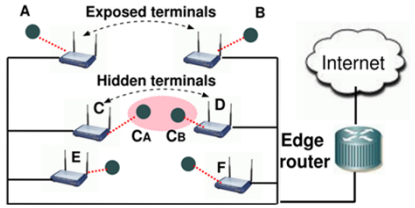
Problematic Scenarios

- Hidden Terminals (HT)
  - ➢Usually the AP ~56% of cases
  - ➢Worse if you consider ~80% is downlink
- Exposed Terminals (ET)
  - ➢ Hard to Detect (Disable CS)



Shrivastava, V. et. al. CENTAUR: Realizing the Full Potential of Centralized WLANs through a Hybrid Data Path (2009).

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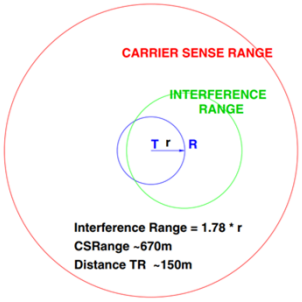
Problematic Scenarios

III. Observations on Carrier Sensing in 802.11



Vasan, A. et. al. Echos - Enhanced Capacity 802.1.1 hotspots (2005).

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Solutions

- Centralized Network Architecture:
  - ➢ Frames
    - Timing (Delay)
    - Staggering Packets (Sync transmissions)
    - Aggregation of Packets and Acks

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  - APs
    - Disable CS (for ET)(raise the CCA exploit)
    - Fixed back-off (ET exploit)
    - Directional Antennas (Isolation)
    - Spectrum Sensing (CCA)

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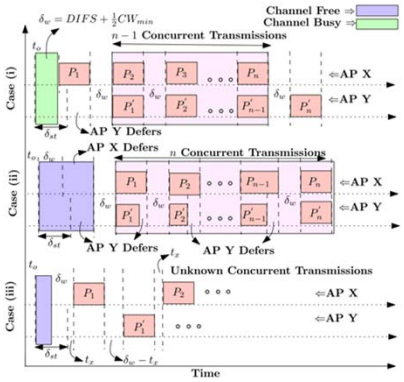
    - Spectrum Sensing (CCA)
  - Clients
    - Scheduling (TDMA and variants)
    - CCA Threshold (Capture Effect, Minimize Noise)

Staggering



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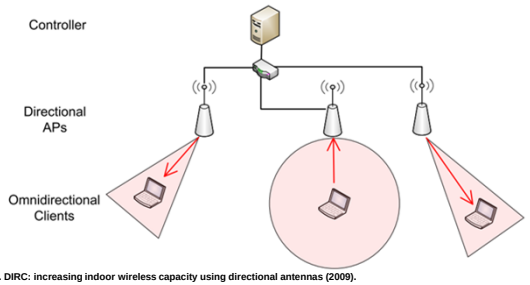
Directional Antennas

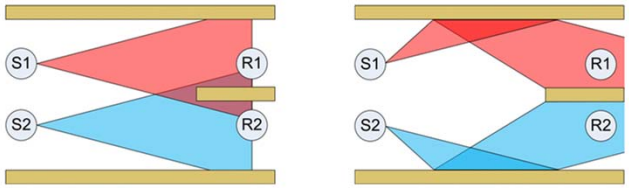
- Spacial Isolation of up to 20 dB (for 10¶ sectors)
- Antenna Steering



Liu, X. et. al. DIRC: increasing indoor wireless capacity using directional antennas (2009).

Directional Antennas

- **Reflections**



(a) Using max SNR/LOS directions

(b) Exploiting reflected paths

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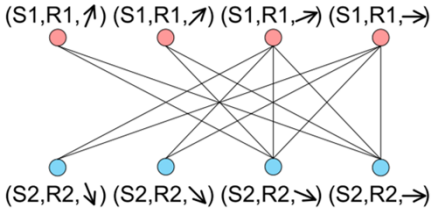
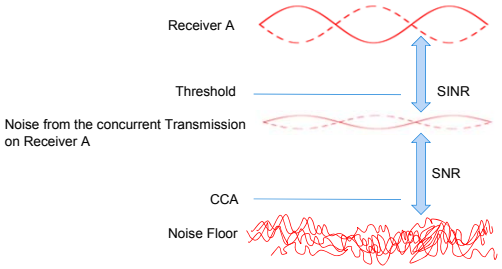
Frqidfw Judskv

- Yhuwlfhv#hsuhvhqw#Nudqvp lvvlrqv
- Hgjh#hsuhvhqw#d#Frqidfw#Lqwhuihuhqfh,
- Yhu|#Khjk#Slp hqvlrqddw|#fdq#eh#vorz #wr#xhu|



SNIR Model

- **The cumulative interference (SNIR) should allow for both messages to be Received**
- **Optimize Power Control to minimize Graph Conflicts**



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SNIR Model

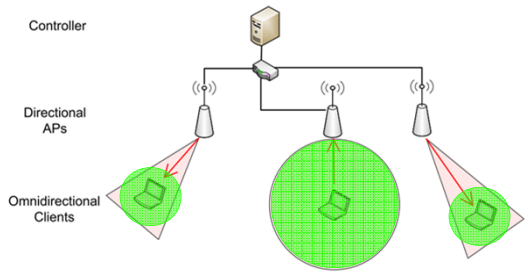
- **Rate Dependent**
- **Fairness (between the Concurrent Receivers)**

Table 1: For BERs less than or equal to 10^{-5}, the minimum *SINR* required to support the corresponding data rate.

Rates (Mbps)	*SINR* (dB)	Modulation	Coding Rate
54	24.56	64-QAM	3/4
48	24.05	64-QAM	2/3
36	18.80	16-QAM	3/4
24	17.04	16-QAM	1/2
18	10.79	QPSK	3/4
12	9.03	QPSK	1/2
9	7.78	BPSK	3/4
6	6.02	BPSK	1/2

Kim, T. et. al. Improving spatial reuse through tuning transmit power, carrier sense threshold, and data rate in multihop wireless networks

CCA & Power Control



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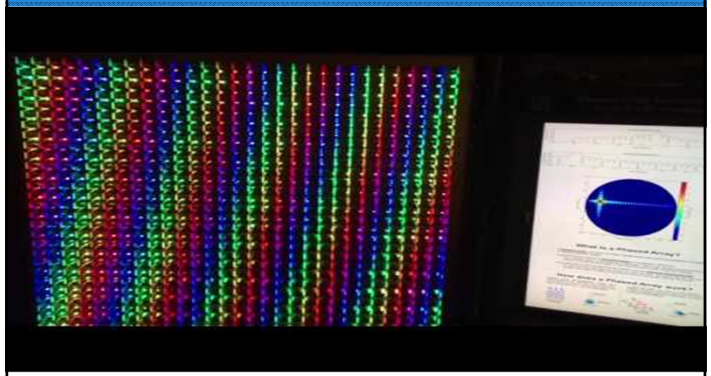
Phased Array Antenna Demo Video

Phased Array Antenna Demo



Phased Array Demonstration System built by MIT Lincoln Laboratory (https://www.ll.mit.edu/) and shown at the 2016 IEEE International Symposium on Phased Array Systems and Technology (http://www.array2016.org/). https://www.youtube.com/watch?v=mzhMUH-Q8kY

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Thank You!

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