Weeble: Enabling Low-Power Nodes to Coexist with High-Power Nodes in White Space Networks

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Outline

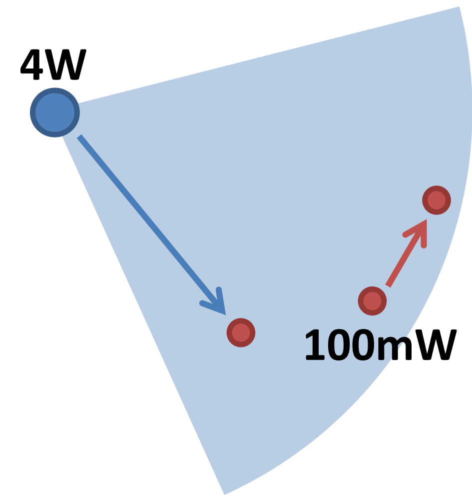
1. Introduction
2. Weeble MAC
3. Weeble PHY
4. Evaluation
5. Summary

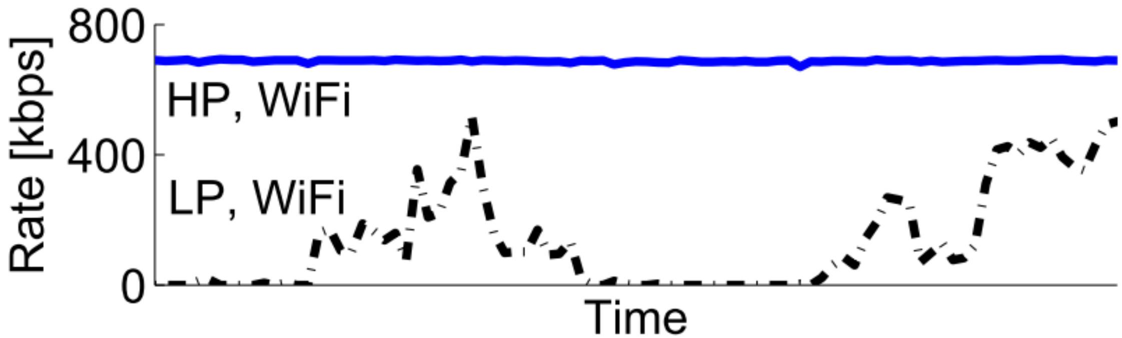
White-spaces

- TV White spaces (TVWS)
  - Analogue TV frequencies free after digital swover
  - Good propagation characteristics
- Parts offered for unlicensed use
  - FCC (US), Ofcom (UK), Canada, more to follow
  - Application
    - Cheap/free access (cellular offload, home)
    - Long-distance (rural, M2M)
- Standards: 802.22 (centr.), **802.11af** (CSMA)

Coexistence in 802.11af (CSMA)

- Two types of transmitters
  - 4W fixed base-stations (HP)
  - 100mW mobile terminals (LP)
- Problem:
  - Carrier sense does not work
  - How to prevent starvation?





Throughput measured in our indoor white-space test-bed

Frequency Division?

- Centralized algorithm for frequency assignments:
  - Global and dynamic
  - Account for varying population and mobility
  - Static can be very inefficient
    - Now flow-level multiplexing
- Unlicensed networks:
  - No global coordinator to mandate assignments?

Weeble

- Distributed MAC protocol for coexistence
- Goals:
  1. Avoid starvations
  2. Avoid performance degradations of long links
  3. Increase total throughput
- Overview:
  - PHY: adaptive preamble detection at low SNR
  - MAC: Recover CSMA using PHY detector

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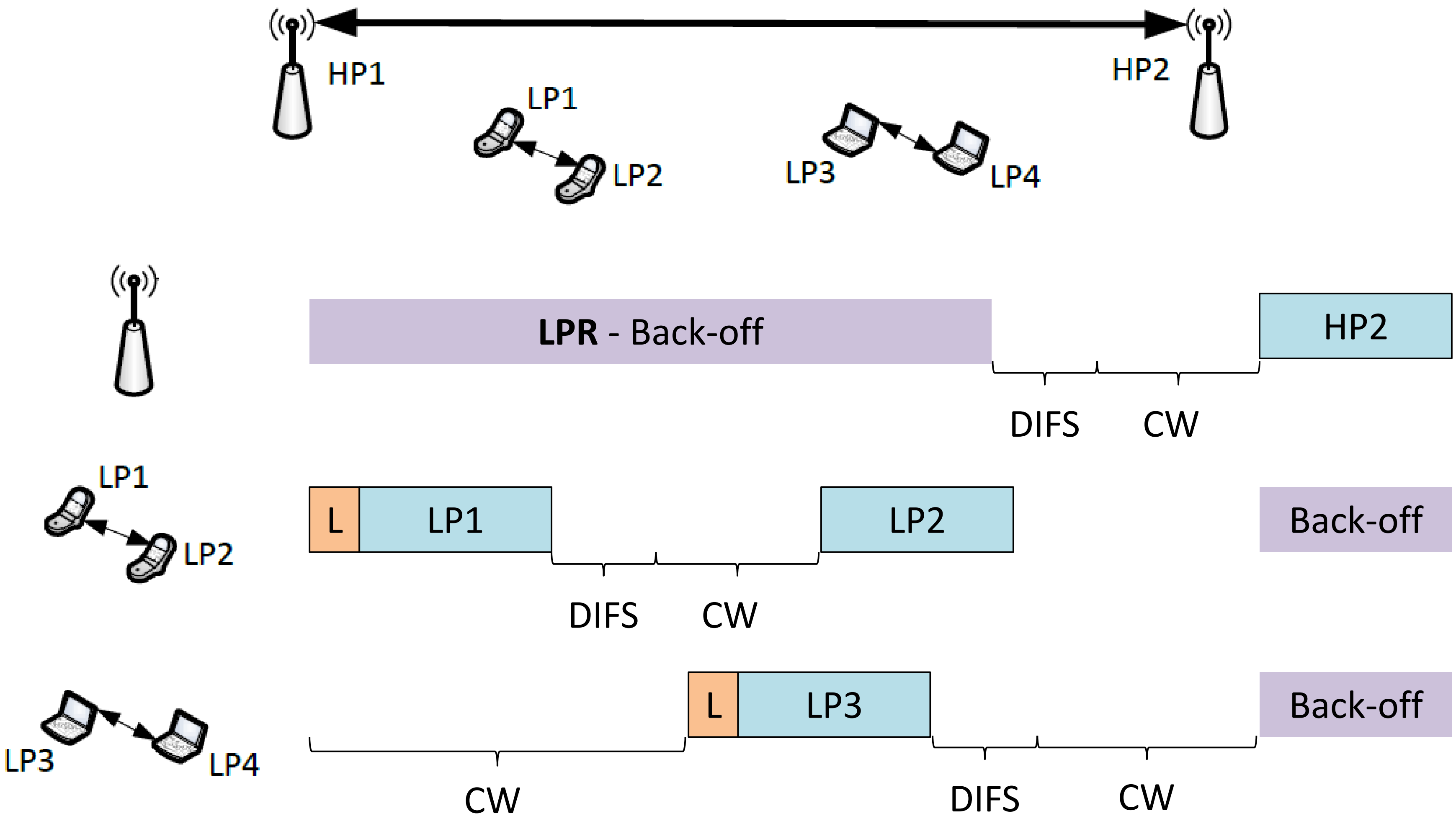
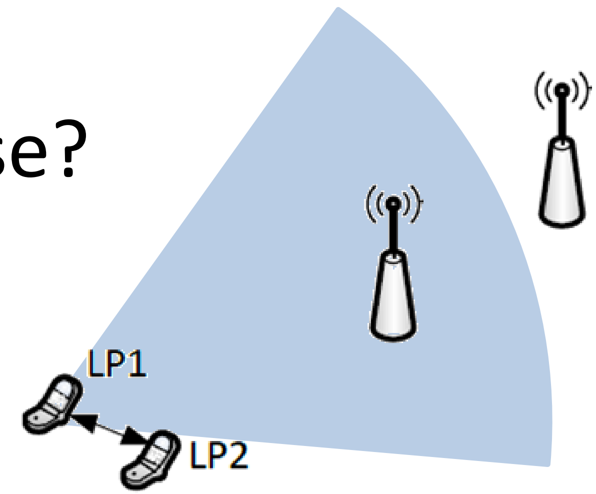
Weeble MAC Overview



Algorithm to adapt preamble length



- What preamble length to choose?
  - Too short: collisions
  - Too long: low spatial reuse
- Observation:
  - Consecutive losses at LP likely only when a hidden HP transmits concurrently
- Idea:
  - AIMD Adaptive algorithm based on the number of consecutive losses

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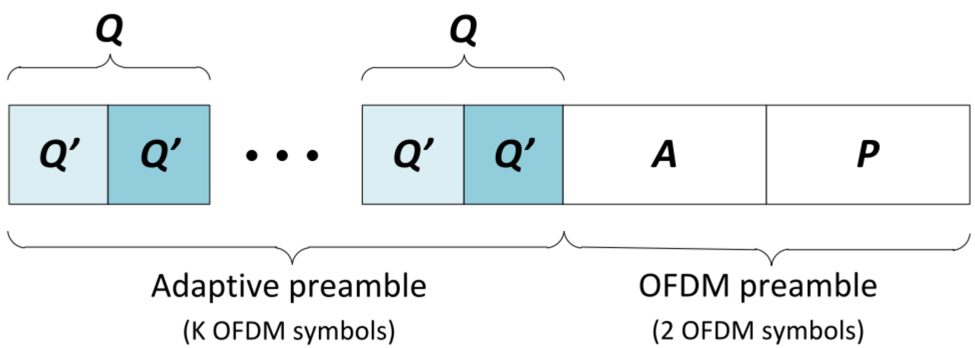
Weeble PHY Overview

- Detection requirements: ~-16dB
  - 4W / 100mW = 16dB
- Probability of detection = O(sqrt(preamb. size))
  - Meet requirements by increasing preamble size
- Problems:
  - Detection wall (due to internal noise)
  - Long preambles – large overhead/complexity
  - Long preambles – low spatial reuse – adaptation
  - False positives from ordinary HP transmissions

Repetitive preambles

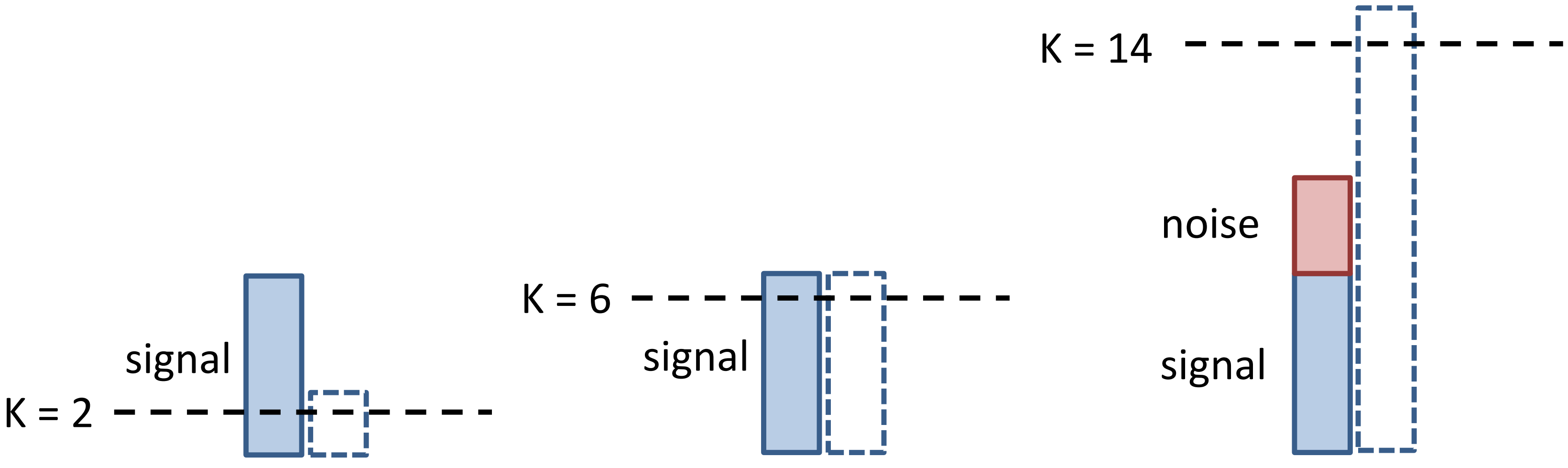
- **Only detection, no time synchronization**



- K #repetition of mini preamble **Q** (K – arbitrary)
- Low complexity

Adaptive Preamble Length

- Correlator does not need to know K apriori
  - 4 parallel detector for K = {2, 6, 10, 14}
  - Signal detected if any of 4 output detects
- Example: K = 6



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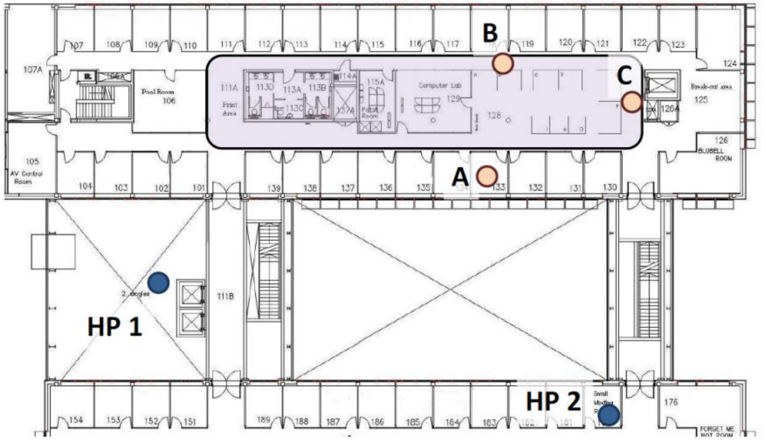
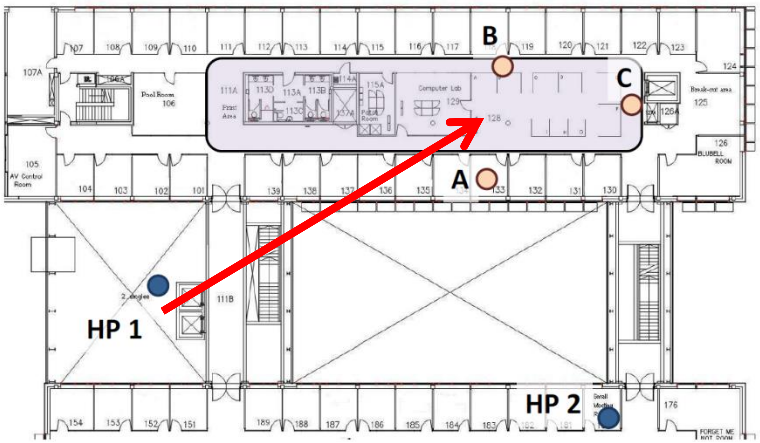
Evaluation

- Implemented on Lyrtech SDR
  - MAC in DSP, PHY in FPGA
- Large-scale simulation in Qualnet
- Test-bed:
  - Across 3 floors
  - 2 HP nodes
  - 2 LP nodes
    (different locations)



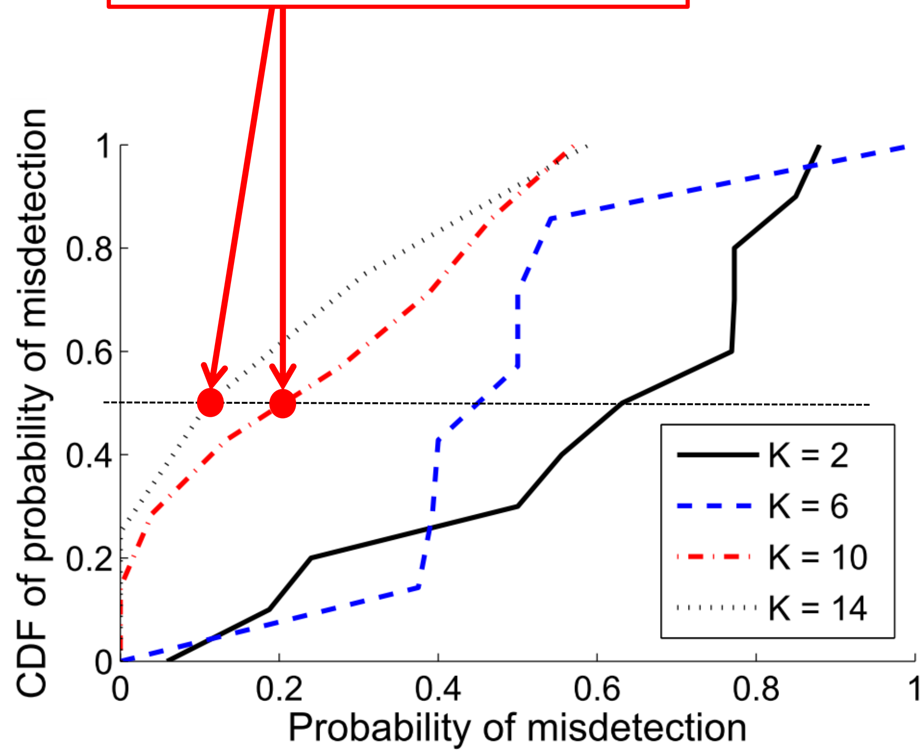
Office building

PHY Measurements



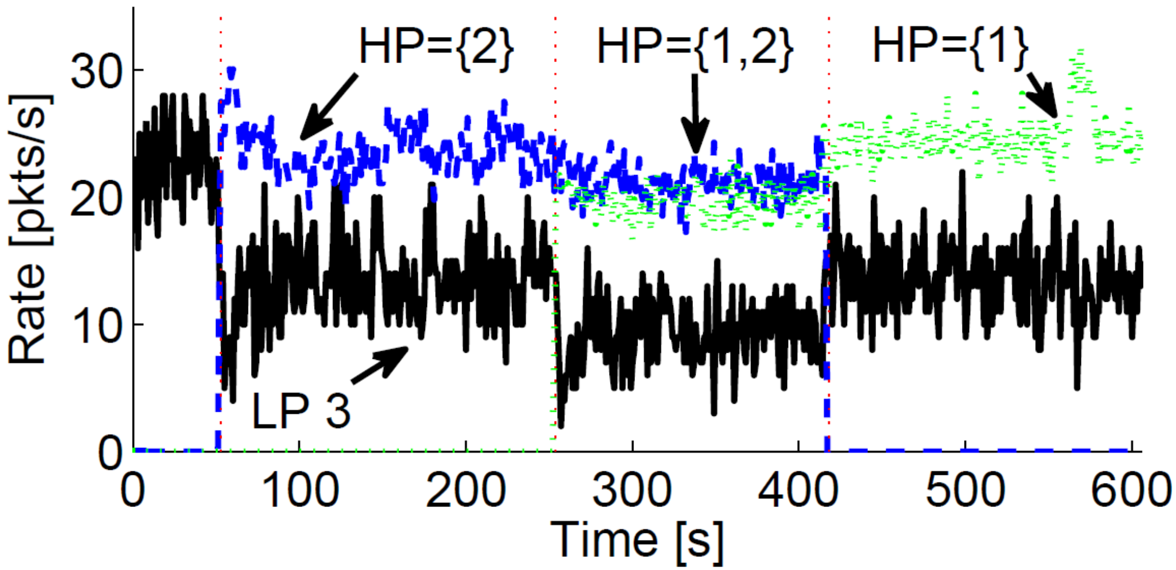
- Measure probability of misdetection of packet batch at different locations
- Plot CDF across locations

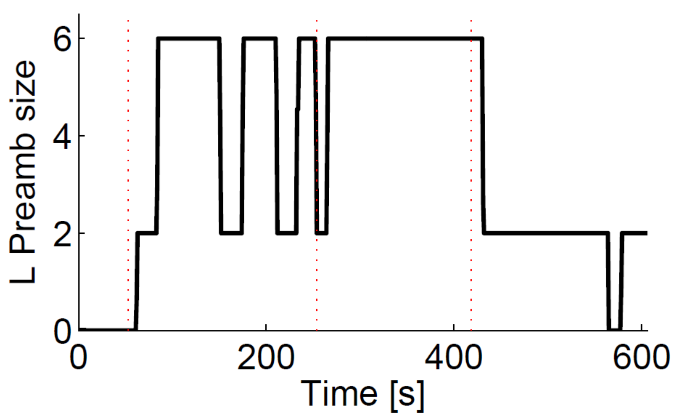
Median location will have *80%* accuracy for *K=10* and *90%* accuracy for *K=14* at SNR = *-16.5*dB

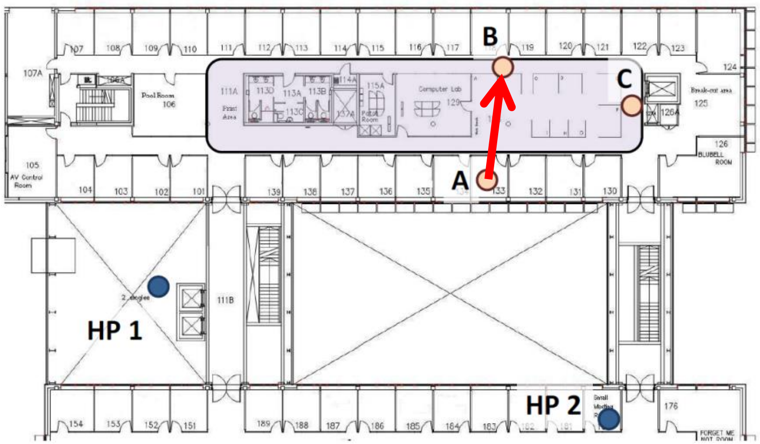


SNR = -16.5 dB

Weeble in Action

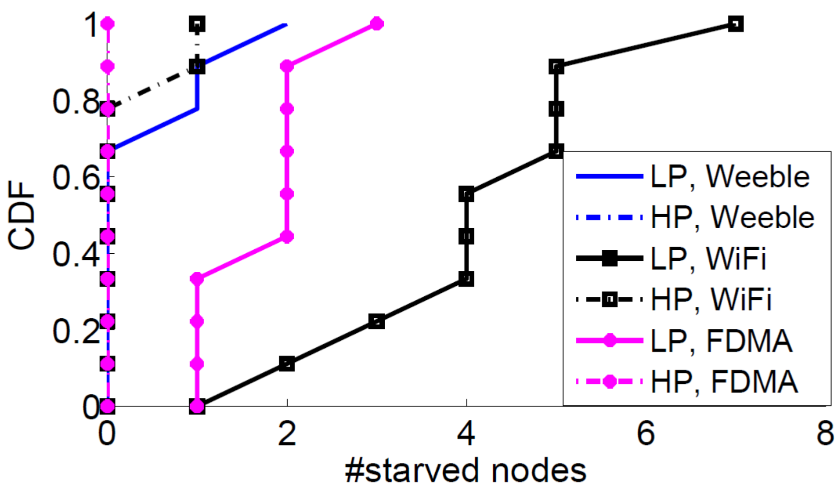




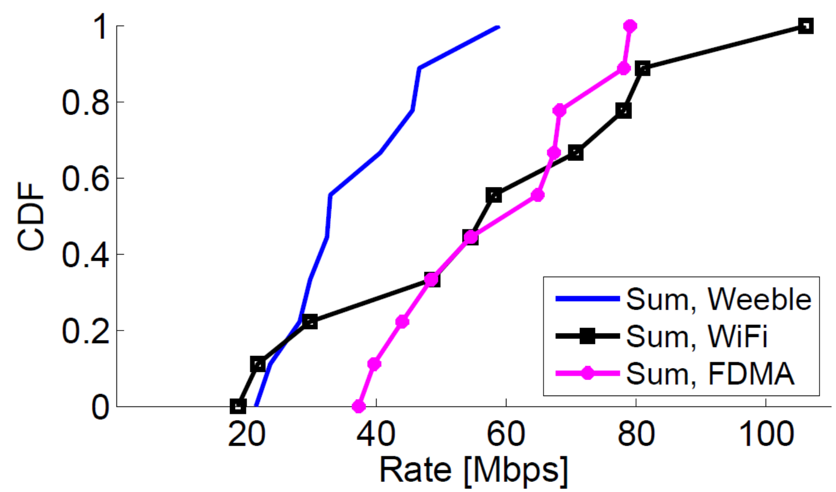


Fairness vs. Efficiency

Fairness



Efficiency



- Starved flow = TCP flow with rate ≤ 100 kbps

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Weeble Summary

- We consider coexistence problem in 802.11af
- Weeble PHY:
  - Little extra logic/silicon
  - Use adaptive preambles to avoid starvation while maximizing spatial reuse and minimizing overhead
  - Use L and H preamble to avoid false positives
- Weeble MAC:
  - Distributed, contention based MAC
  - Algorithm for adapting preamble lengths

THANK YOU!