I&C School – Laboratory for Communications and Applications (LCA 3)

SAW: Spectrum Assignment for WLANs

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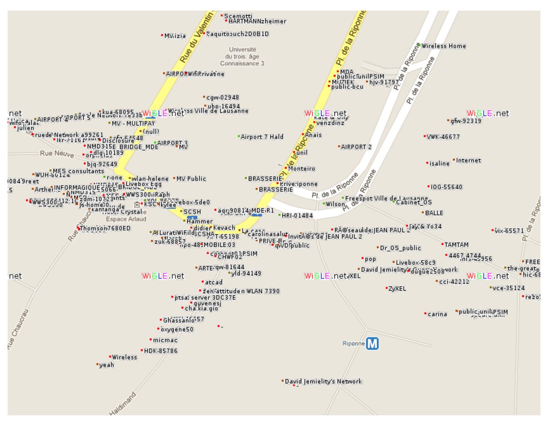
Context

- Interfering neighboring wi-fi home/office networks
- Chaotic spatial repartition, heterogenous densities

Manhattan



Lausanne

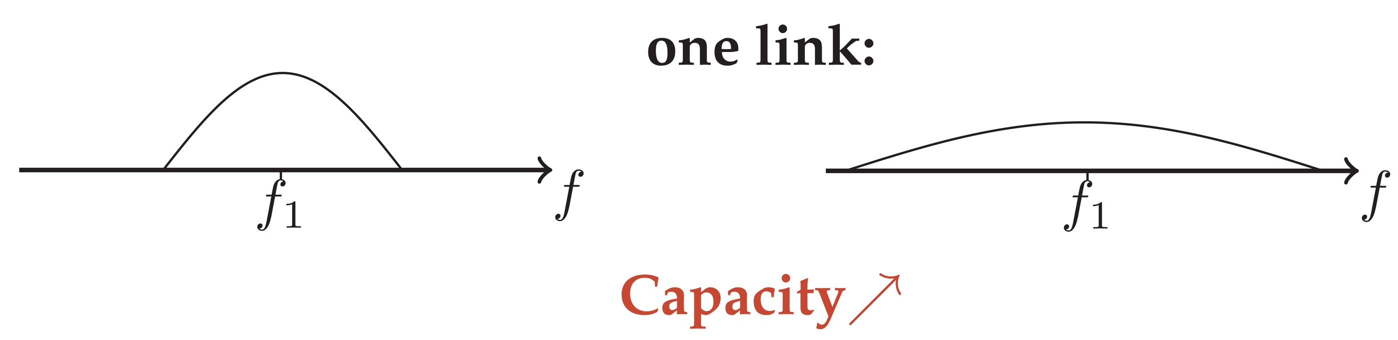
- Several possible channels (center frequencies)
- Variable channel bandwidths ($5 \to 20 \to 40 \to 160$ MHz)
- Limited spectrum available
- No central control

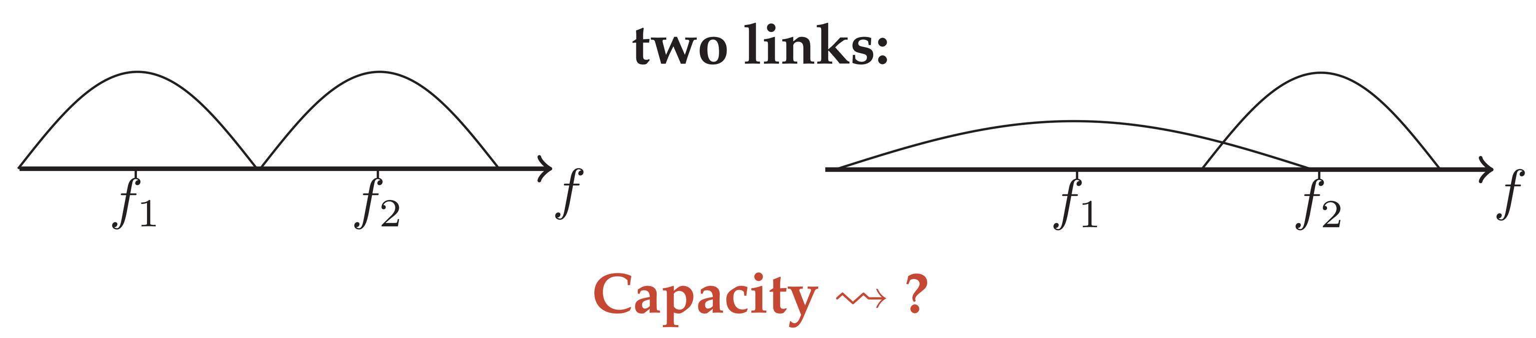
Problem

Goal: Joint allocation of channel **center frequency** and **bandwidth**.

Main challenge: Conflicting goals between interference mitigation and capacity maximization.

- Bandwidth↗ $\Rightarrow$ Capacity↗
- Bandwidth↗ $\Rightarrow$ Interference likelihood↗





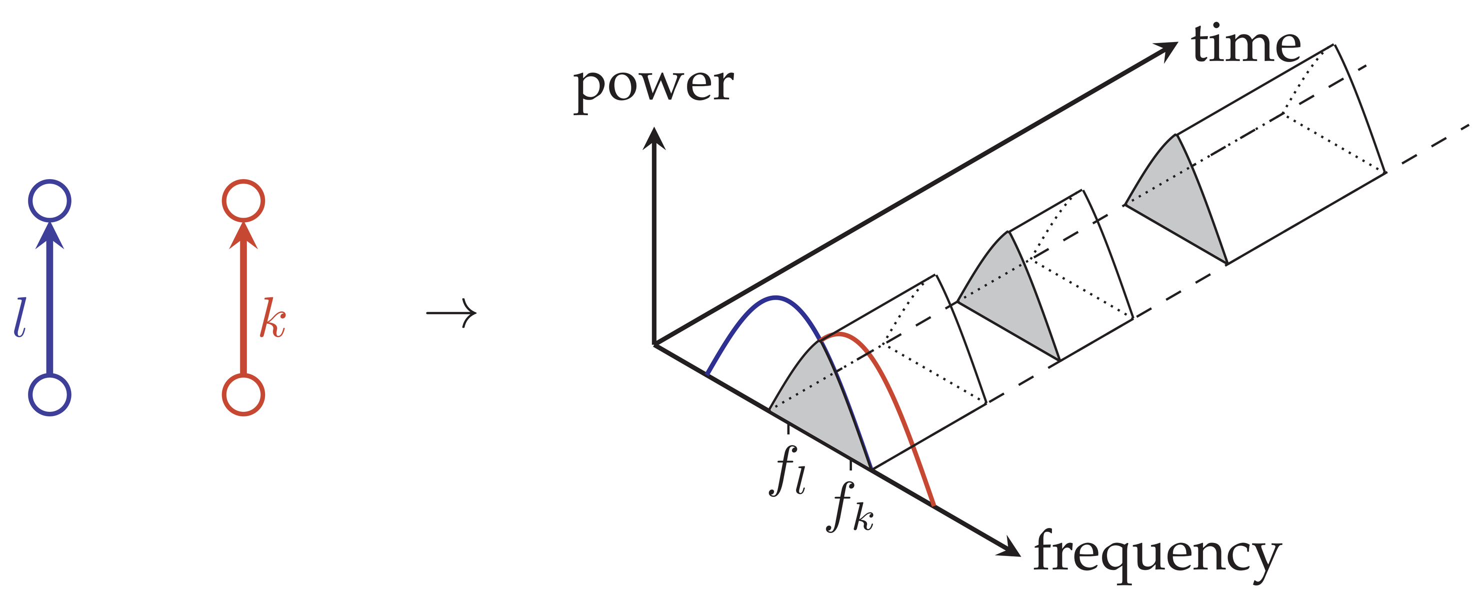
Design Objectives:

- **Decentralized** algorithm
- **Global convergence** guarantees
- **Online** for adaptivity to time-varying conditions
- **Transparent** to user traffic
- **Practical** for implementation on off-the-shelf 802.11 hardware

Interference Model

- Consider two links k and l. We model the interference produced by k on l as:

$$I_l(k) := \textbf{airtime}(k) \cdot \textbf{frequency overlap}(k,l)$$



- A BSS is a set of links that comprises an access point. For two BSSs A and B, the interference produced by B on A is

$$I_A(B) := \sum_{l \in A} \sum_{k \in B} I_l(k)$$

Algorithm

Optimization Objective: Explicit interference vs. bandwidth trade-off.

$$\text{minimize} \quad \mathcal{E} := \underbrace{\sum_A \sum_{B \in \mathcal{N}_A} I_A(B)}_{\text{Total interference}} + \underbrace{\sum_A \text{cost}_A(b_A)}_{\text{Sum of bandwidth "costs"}}$$

- $\text{cost}_A(b_A)$ is the cost that BSS A attributes to using bandwidth b_A. We use $\text{cost}_A(b_A) \propto 1/b_A$ to favorize wider bandwidths.

SAW Algorithm at BSS A:

Initialization:
- Pick a random configuration (f_A, b_A)

After random (exp. distributed) time intervals:
- Pick a random configuration $(f_{\text{new}}, b_{\text{new}})$
- Measure $e_1 := \sum_{B \in \mathcal{N}_A} (I_A(B) + I_B(A)) + \text{cost}_A(b_A)$ if A uses (f_A, b_A)
- Measure $e_2 := \sum_{B \in \mathcal{N}_A} (I_A(B) + I_B(A)) + \text{cost}_A(b_{\text{new}})$ if A uses $(f_{\text{new}}, b_{\text{new}})$
- Compute

$$\beta_T = \begin{cases} 1 & \text{if } e_2 < e_1 \\ \exp \frac{e_1 - e_2}{T} & \text{else} \end{cases}$$

- Set $(f_A, b_A) = (f_{\text{new}}, b_{\text{new}})$ with probability β_T

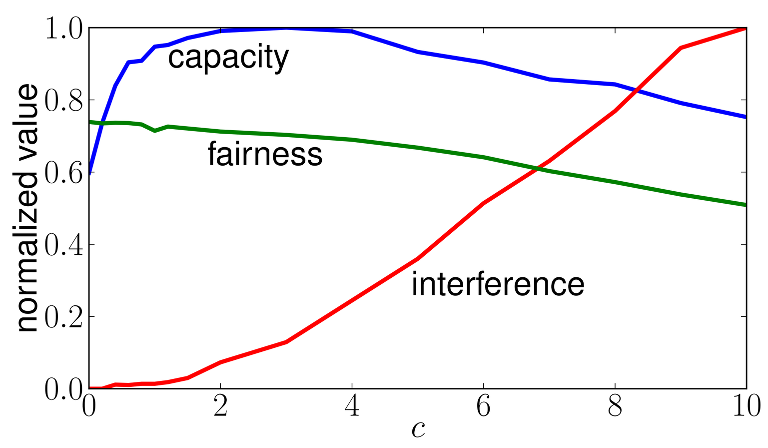
Convergence: Denote X_n the global state of the network after the n-th iteration. Consider a network where all the BSSs run SAW using a given *temperature* parameter T. Then X_n is a Markov chain, and it converges in distribution to $\pi(X) \propto e^{-\mathcal{E}(X)/T}$.

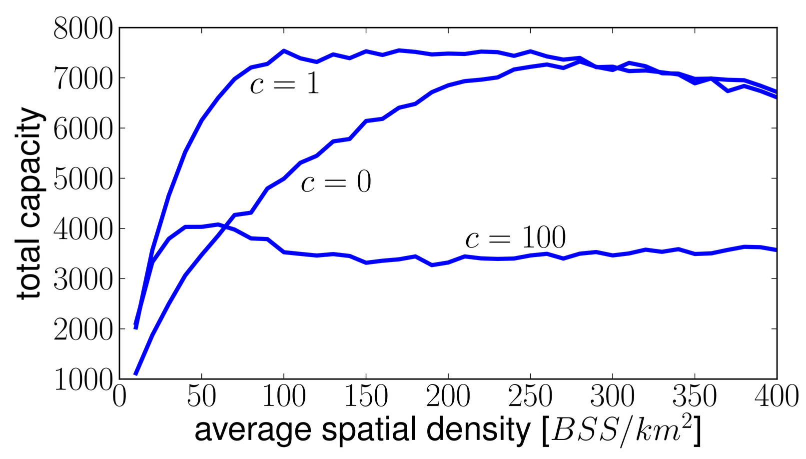
$\Rightarrow$ State gets arbitrarily close to optimal for T small enough.

Results

Simulation Results:

- We use $\text{cost}_A(b_A) = c/b_A$, for some constant $c \geq 0$. Minimization objective becomes: $\sum_A \sum_{B \in \mathcal{N}_A} I_A(B) + \mathbf{c} \cdot \sum_A \mathbf{1/b_A}$.
- $c = 0$: minimize interference
- $c \to \infty$: use largest bandwidth, irrespective of interference
- Best operating point should depend on network spatial density



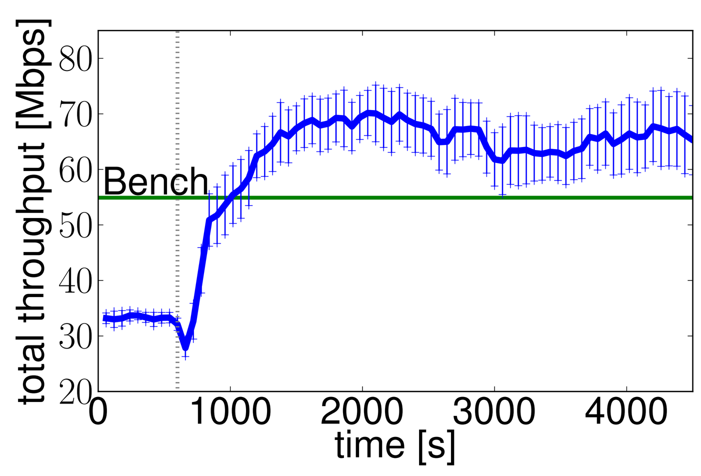


$\Rightarrow$ **A single value of c gives the best performance for all network spatial densities!**

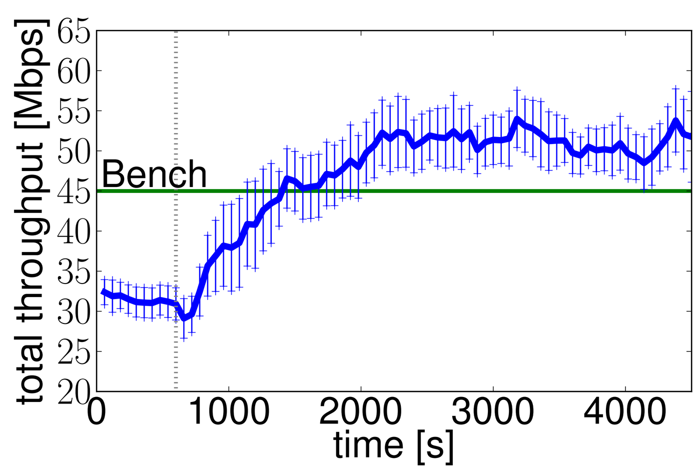
Testbed Results:

- Experiments with 10 BSSs composed of 21 IEEE 802.11 nodes
- Comparison with a **centralized** graph-coloring algorithm for **fixed-width** channel allocation ("Bench" line)

UDP traffic:



TCP traffic:



References

[1] J. Herzen, R. Merz, P. Thiran. Distributed Spectrum Assignment for Home WLANs. In *IEEE Infocom '13*