The Power of Non-Uniform Wireless Power

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Wireless Communication

Wireless Communication

EE, Physics

Maxwell Equations

Simulation, Testing

‘Scaling Laws’

Network Algorithms

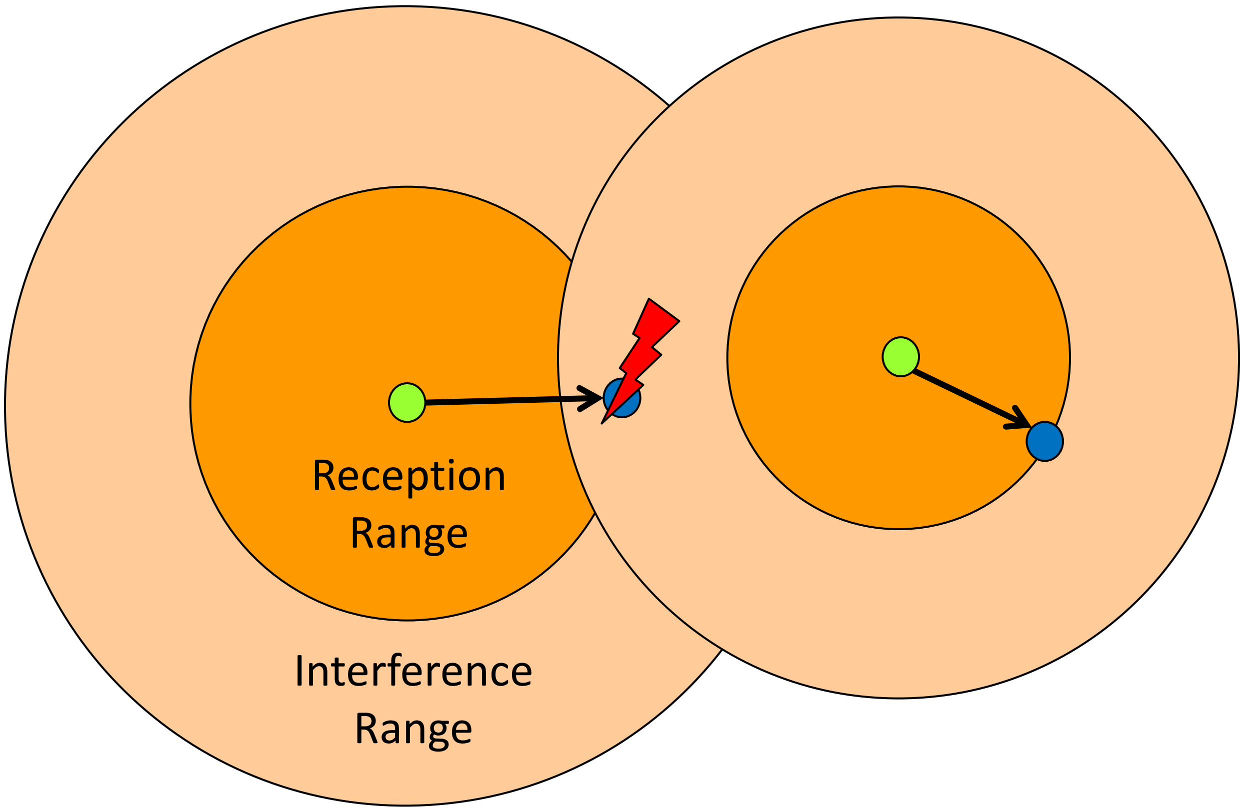
CS, Applied Math

[Geometric] Graphs

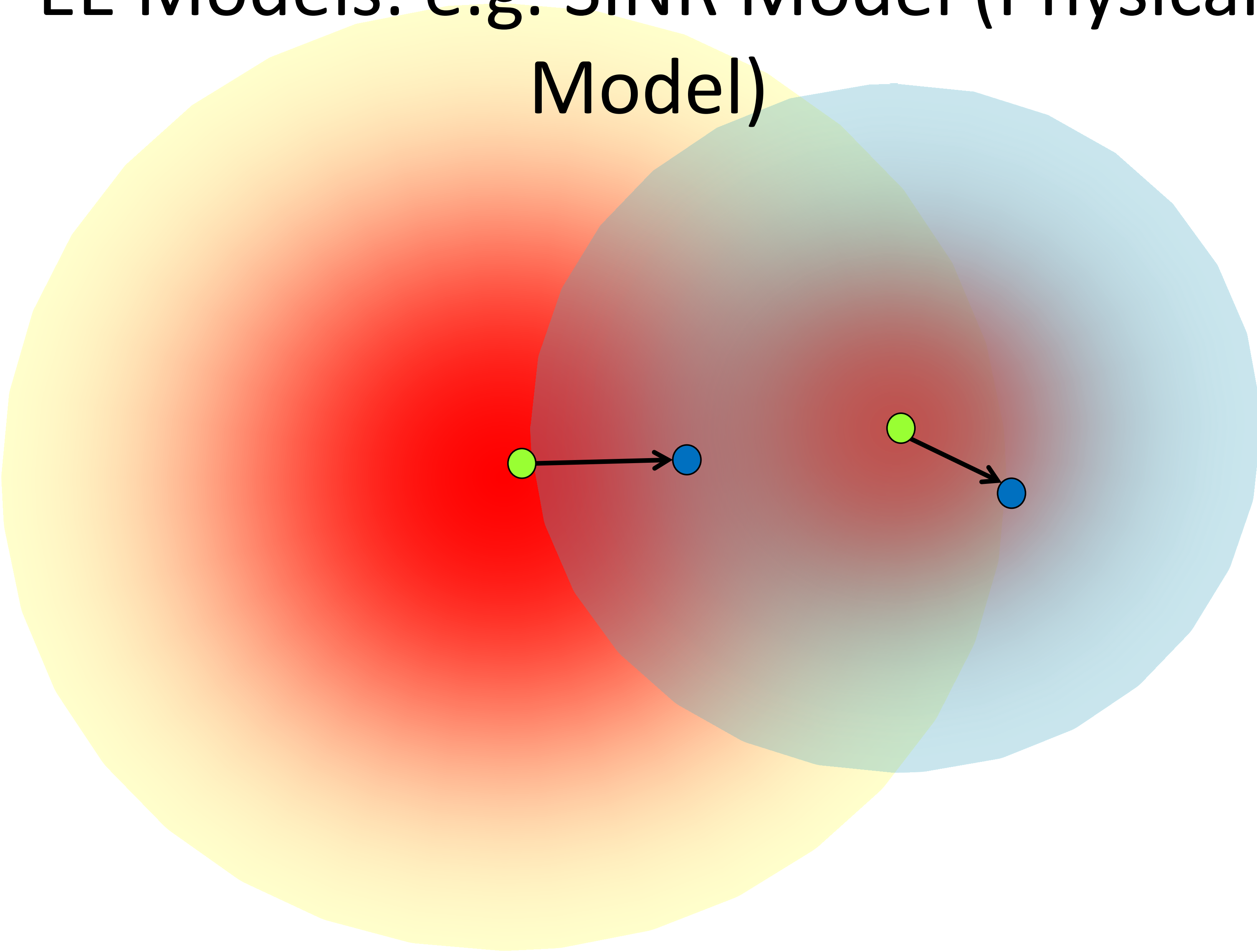
Worst-Case Analysis

Any-Case Analysis

CS Models: e.g. Disk Model (Protocol Model)



EE Models: e.g. SINR Model (Physical Model)



Signal-To-Interference-Plus-Noise Ratio (SINR) Formula

Received signal power from sender

Power level of sender *u*

Path-loss exponent

$$\frac{\frac{P_u}{d(u,v)^\alpha}}{N+\sum_{w\in V\setminus\{u\}}\frac{P_w}{d(w,v)^\alpha}} \geq \beta$$

Minimum signal-to-interference ratio

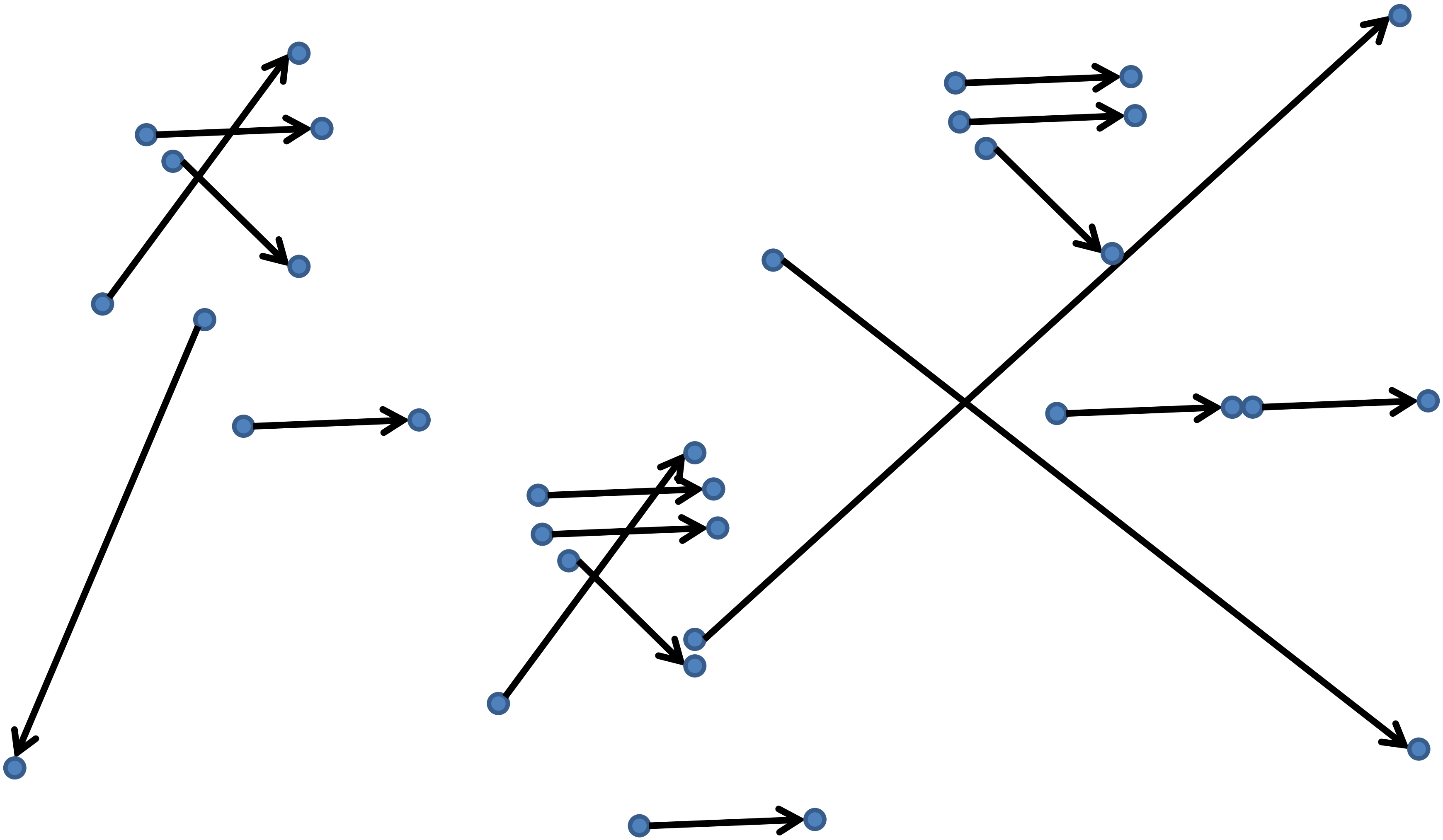
Noise

Received signal power from all other nodes (=interference)

Distance between two nodes

The Capacity of a Network

(How many concurrent wireless transmissions can you have)



… is a well-studied problem in Wireless Communication

The Capacity of Wireless Networks
Gupta, Kumar, 2000

[Arpacioglu et al, IPSN'04]
[Giridhar et al, JSAC'05]
[Barrenechea et al, IPSN'04]
[Liu et al, INFOCOM'03]
[Grossglauser et al, INFOCOM'01]
[Toumpis, TWC'03]
[Gamal et al, INFOCOM'04]
[Kyasanur et al, MOBICOM'05]
[Kodialam et al, MOBICOM'05]
[Gastpar et al, INFOCOM'02]
[Li et al, MOBICOM'01]
[Mitra et al, IPSN'04]
[Zhang et al, INFOCOM'05]
[Bansal et al, INFOCOM'03]
[Dousse et al, INFOCOM'04]
[Yi et al, MOBIHOC'03]
[Perevalov et al, INFOCOM'03]
etc…

The Capacity of a Network

(How many concurrent wireless transmissions can you have)

- Power control helps:
  arbitrarily better than uniform power
  (worst case)

- Arbitrary power: O(1)-Approximation
  Complex optimization problem

- Simpler ways?

Oblivious Power

This Paper

depends on length of link

- Mean power ~~$l^{\alpha/2}$~~ $p\alpha \; : p \in (0,1)$ has "star status"

O(~~$\log n$~~ + $\log\log\Delta$)-approximation [SODA'11]

$\Omega(\log\log\Delta)$ [ESA'09]

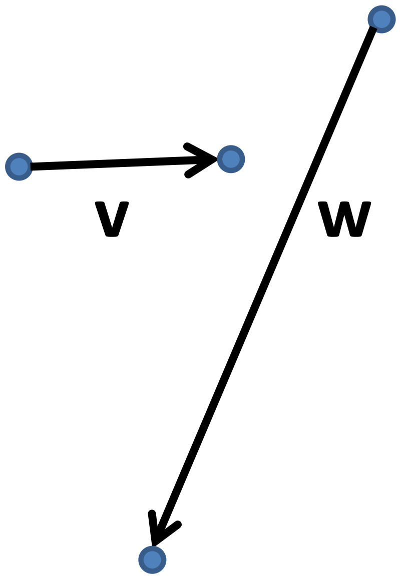
$$\Delta = \frac{maximal\ length}{minimal\ length}$$

(usually: small constant)

Essentially:

O($\log\ n$) vs. $\Omega(1)$

Old Definitions



- Affectance $a_w(v) := c_v \frac{P_w / d_{wv}^{\alpha}}{P_v / l_v^{\alpha}}$
- $a_S(v) := \sum_{w \in S} a_w(v)$
- SINR-condition is now just $a_V(v) \leq 1$
- p-power: assigns power $l^{p\alpha}$: $\mathrm{p} \in (0,1)$ to link l

New Crucial Definitions

- Length-ordered version of symmetric affectance:

$$\hat{b}_w(\mathrm{v}) := \begin{cases} a_v(w) + a_w(v) & : l_v \leq l_w \\ 0 & : else \end{cases}$$

- Interference measure:

$$I_Q^P(L) \quad := \max_{S \subseteq L \; is \; Q-feasible} \; \max_{l_v \in L} \hat{b}_v^P(\mathrm{S})$$

Structural Property

Let P be a p-power power-assignment and Q be an arbitrary power-assignment, then

$$I_Q^P(L) = O(\log\log\Delta)^{*}$$

***= for non-weak links**

Yields $O(log\ log\ \Delta)$-approximation for capacity.
Analysis uses $I_Q^P(L) = O(\log\log\Delta)$

Links $l_1, \ldots, l_n$ increase by length

$S_i := \emptyset$

For i=1 to n do

If $\hat{b}_{S_{i-1}}(l_i) \leq \frac{1}{2}$ then

$S_i := S_{i-1} \cup \{l_i\}$

$X := \{l_v \in S_n : a_{S_n}(v) \leq 1\}$

Applications

Connectivity: given a set of nodes, connect them in an interference aware manner.

Strongly connected in

$O(\log n \cdot (\log n + \log\log\Delta))$ time slots

using ~~mean power~~. any p-power

Centralized and distributed algorithms

Applications

Distributed Scheduling: schedule a given set of links in a minimal number of time slots.

There is randomized distributed $O(\log n \cdot (\log n + \log\log\Delta))$-approximation to scheduling using ~~mean power~~. any p-power

Applications

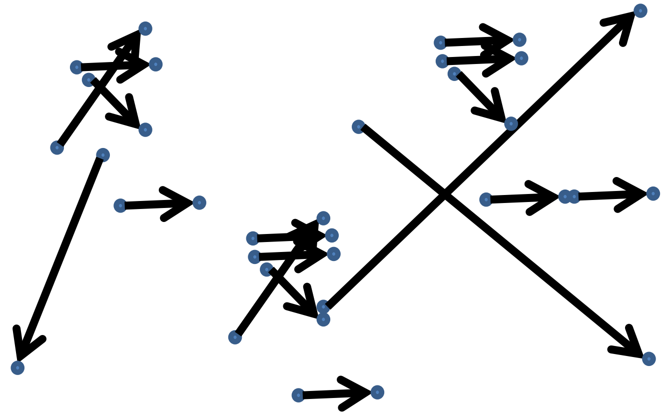
Spectrum Sharing Auctions: k channels, n users, each user has valuation of each subset of channels.

Find: allocation of users to channels such that each channel is assigned a feasible set and the social welfare is maximized.

$O(\sqrt{k} \log n)$-approximation

Summary

SINR-model



capacity max.

Length-oblivious power

$O(\log \log \Delta)$-approximation

3 (out of >5) applications

Thanks!