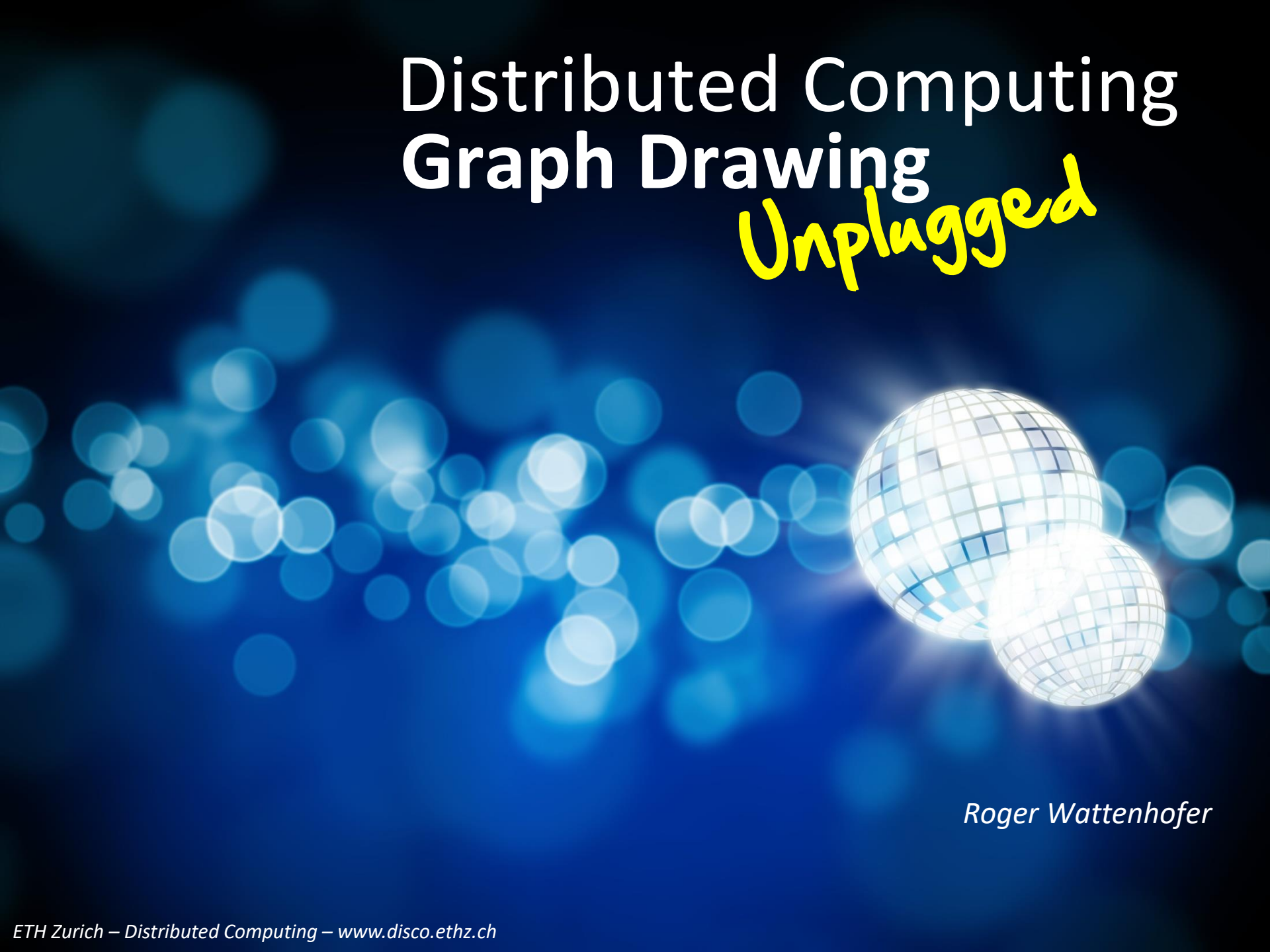
Distributed Computing
Graph Drawing
Unplugged



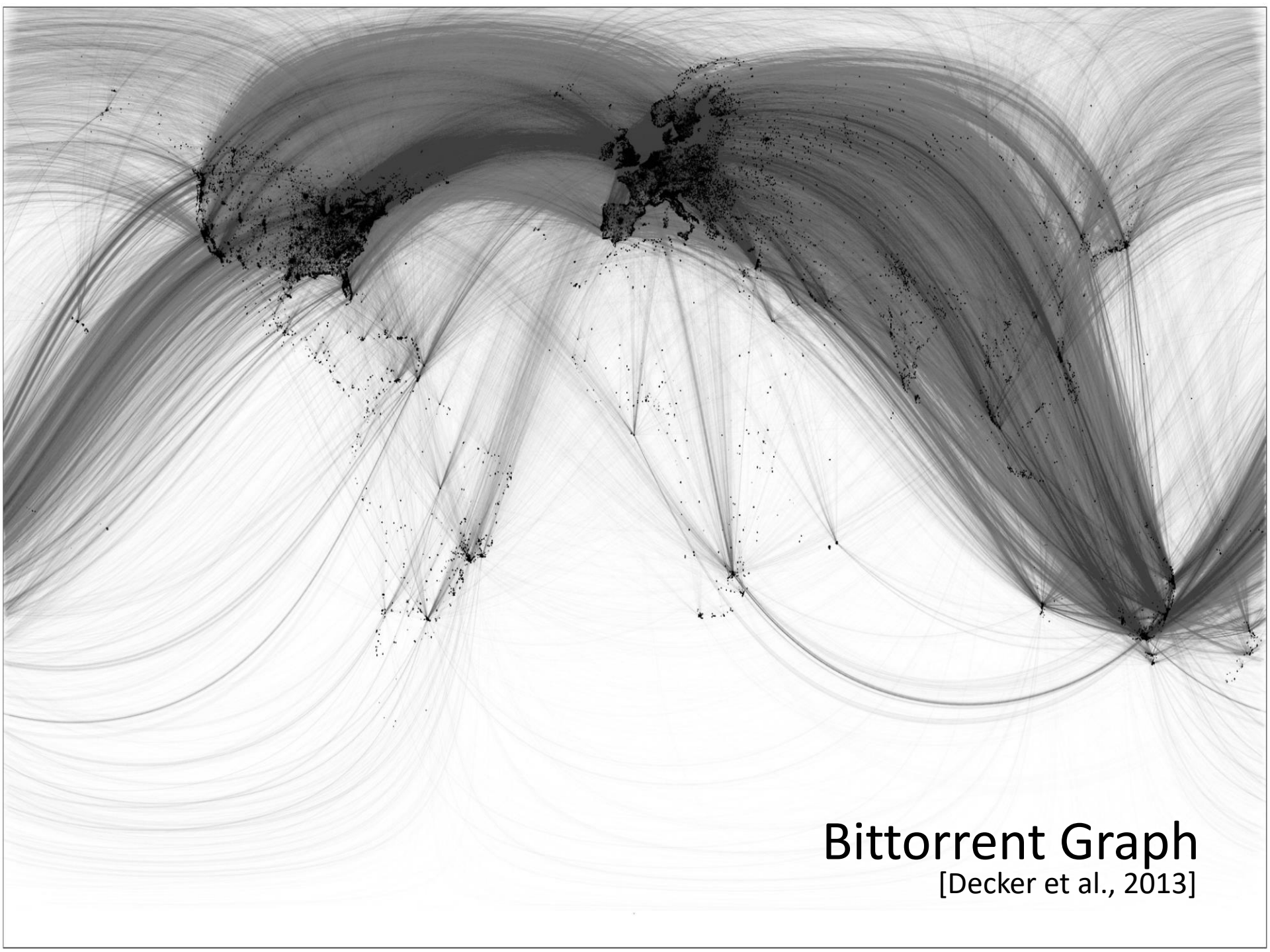
Roger Wattenhofer

Zwei Seelen wohnen, ach! in meiner Brust

My Talk: Open Problem

Draw wireless networks
modeled by something
by using something
to do something.

(plus a few other stories)

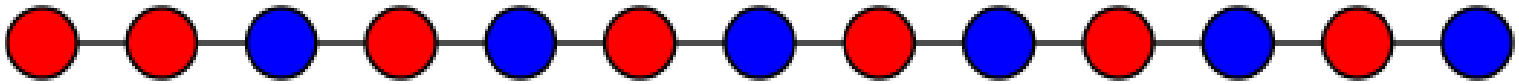


Bittorrent Graph

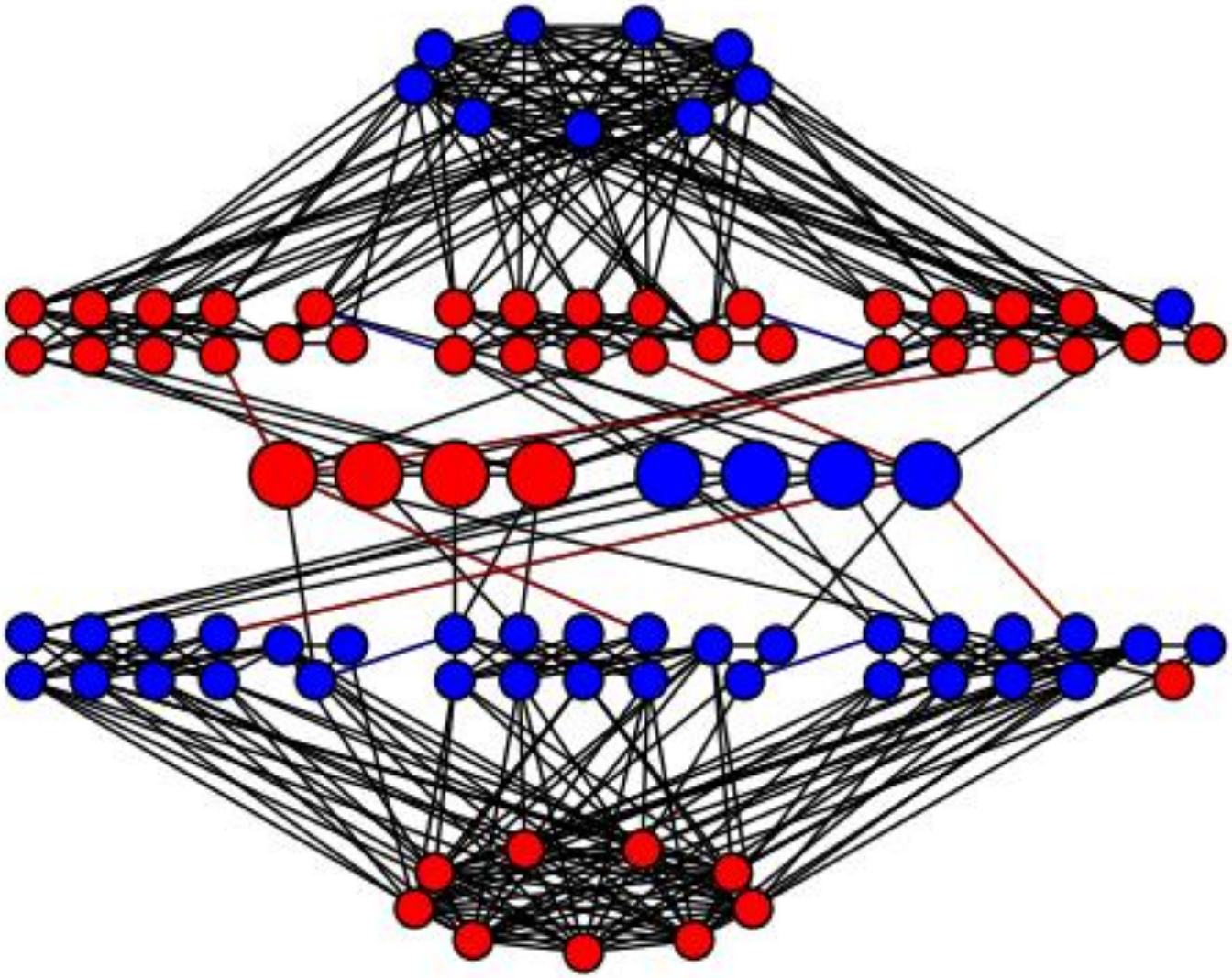
[Decker et al., 2013]

But Graph *Drawing*?

Democrats vs. Republicans Puzzle



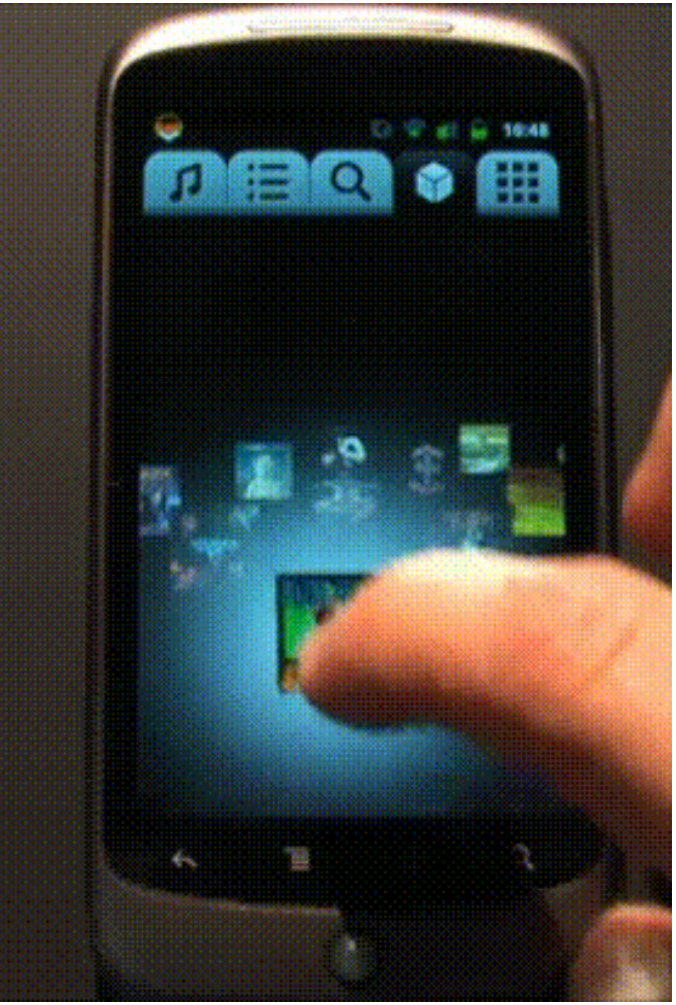
Offended by Ugly Graphs….?



Democrats vs. Republicans Lower Bound Graph

[Frischknecht et al., 2013]

Nodes → Coordinates



Music Graphs

[Bossard et al., 2009]

Drawing Graphs Without Edges!

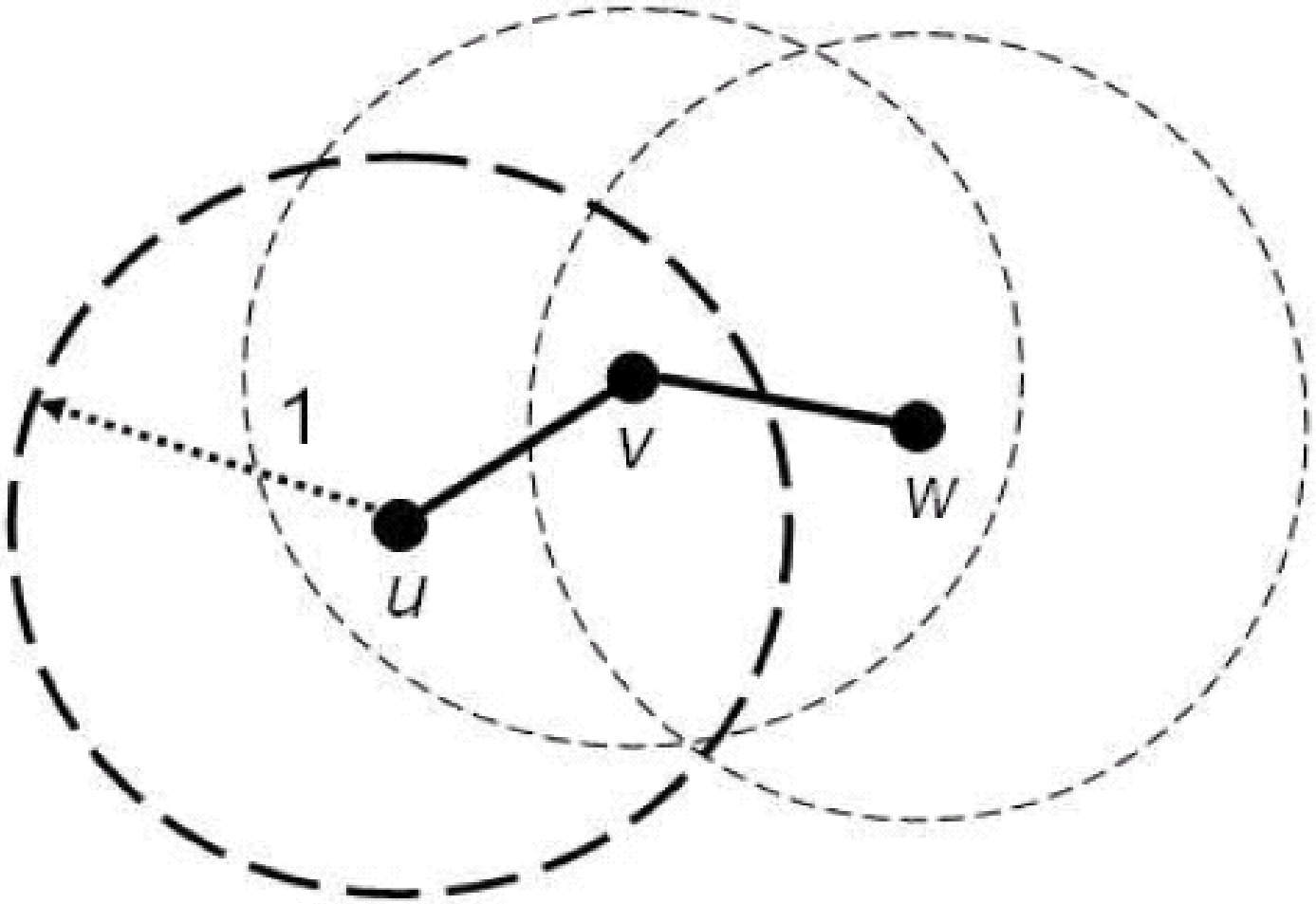
“Only Tiny Graphs Should Have Edges!”

Wireless Networks

Which Node is Which?

Position only from Connectivity

Unit Disk Graph (UDG)

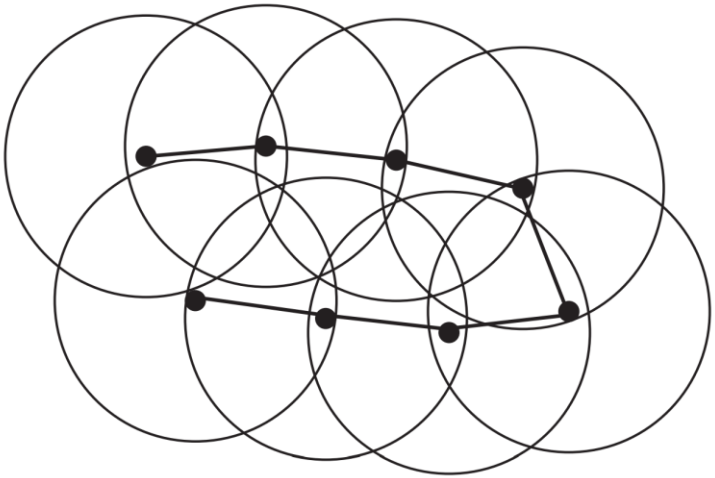


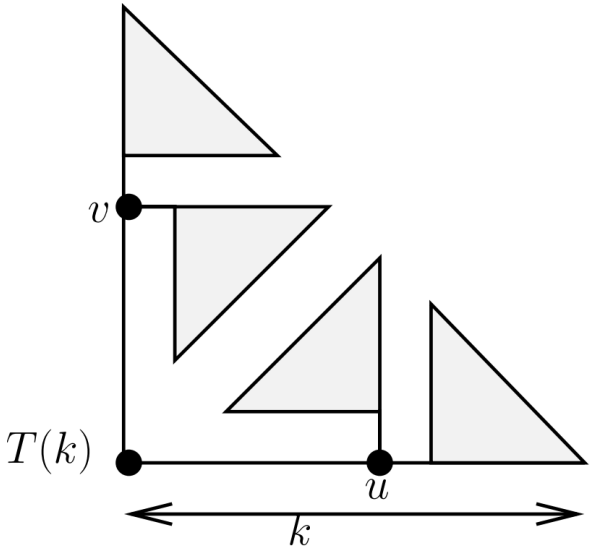
UDG Embedding

1D

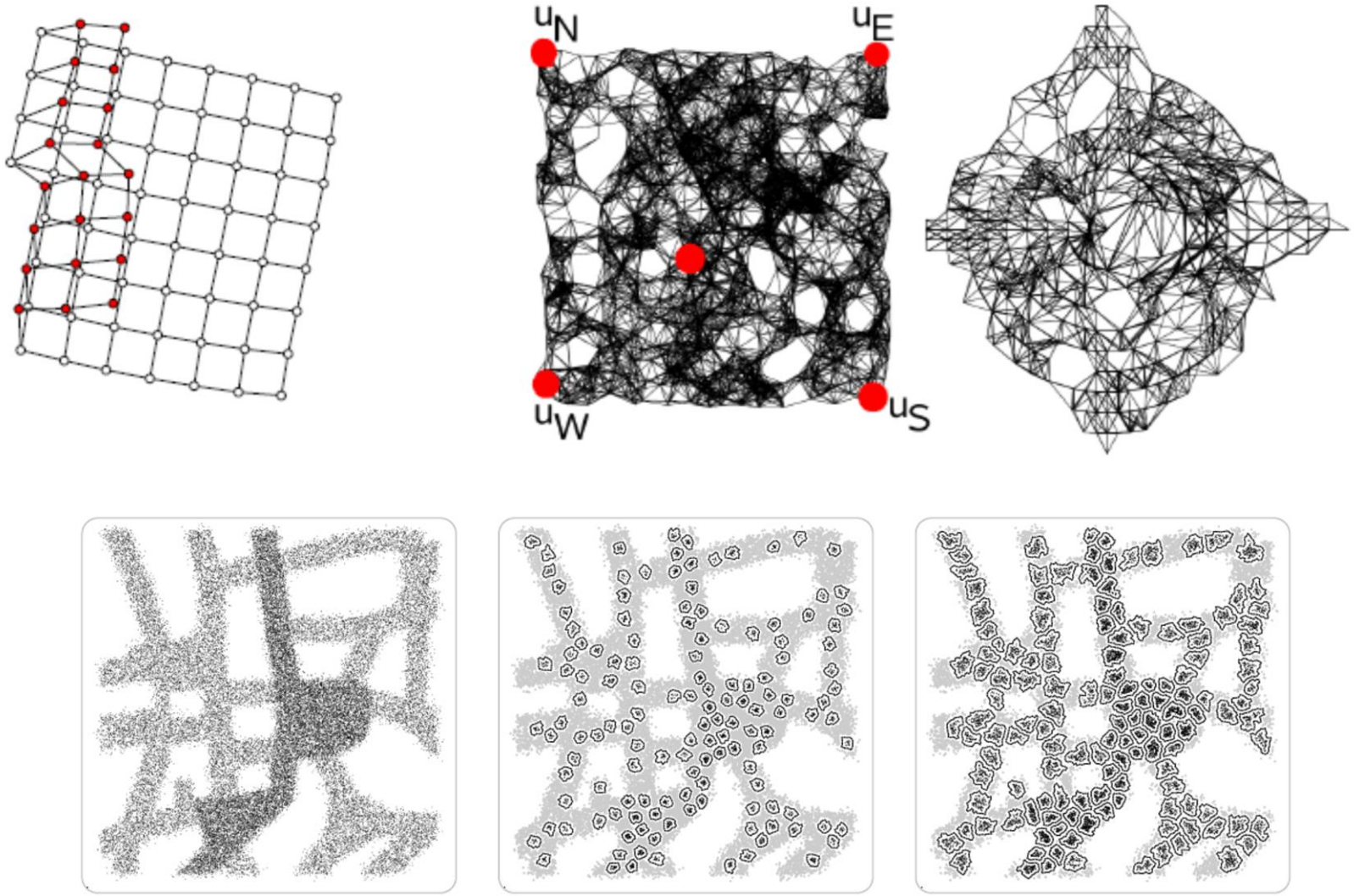
Easy greedy “Hop-Skip” algorithm [O’Dell et al., 2005]

2D





UDG Embedding 2D: Heuristics



e.g., [Priyanta et al., 2003], [Gotsman et al., 2004], [Bruck et al., 2005], [Kröller et al., 2006]

UDG Embedding 2D: Hardness Results

2D

NP-hard, even with exact distance information [Breu, Kirkpatrick, 1998], or angle information [Aspnes et al., 2004] and [Bruck et al., 2004]. Also APX-hard: [Kuhn et al., 2004]

Approximation? $\max d_{\text{no edge}}$ with $d_{\text{edge}} \leq 1$

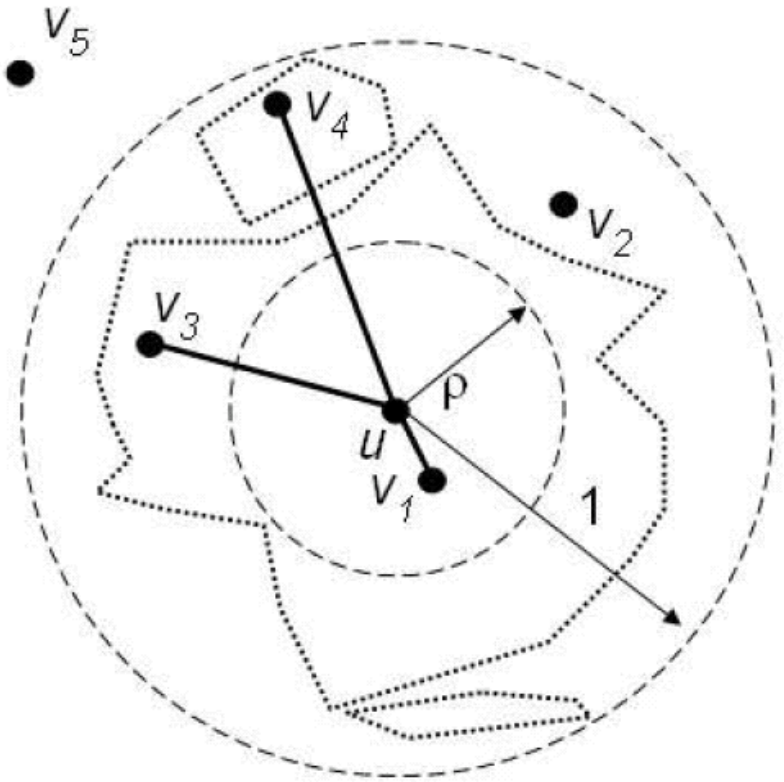
Approximation algorithms: First [Moscibroda et al., 2004]

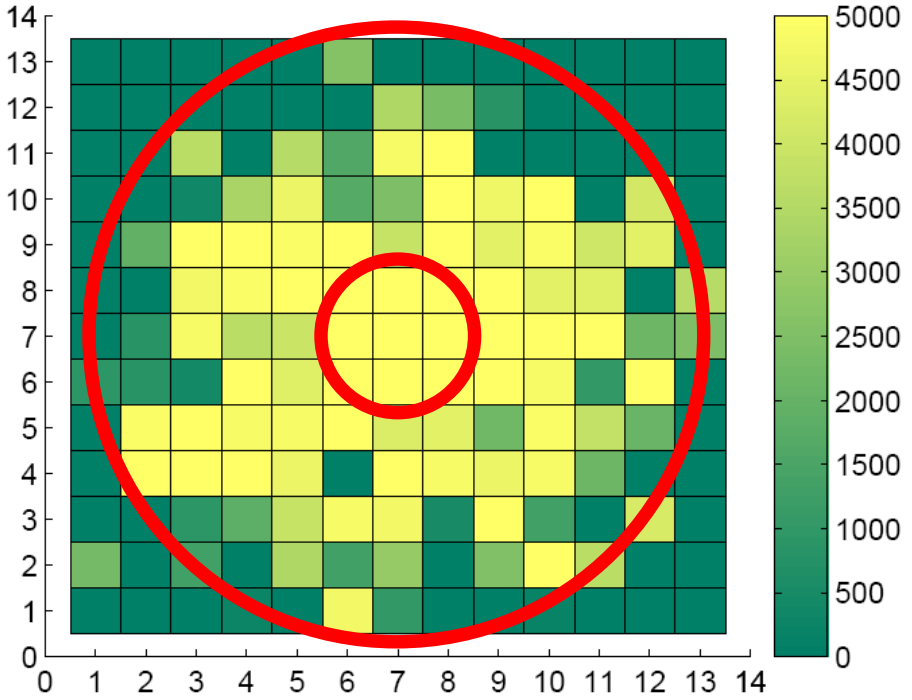
Still best: $O(\log^{2.5} n)$ approximation [Pemmaraju et al., 2006]

Wireless Beyond UDG

If you gave me $100 for each paper written with the unit disk assumption, I still could *not* buy a radio that is unit disk!

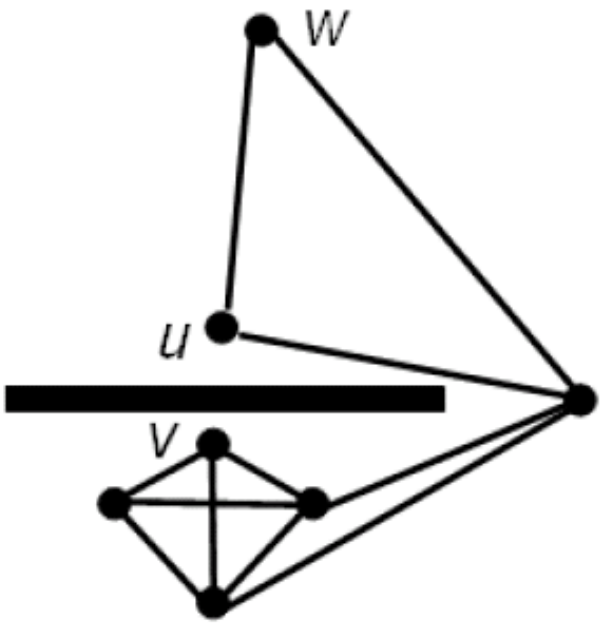
Quasi Unit Disk Graph (QUDG)

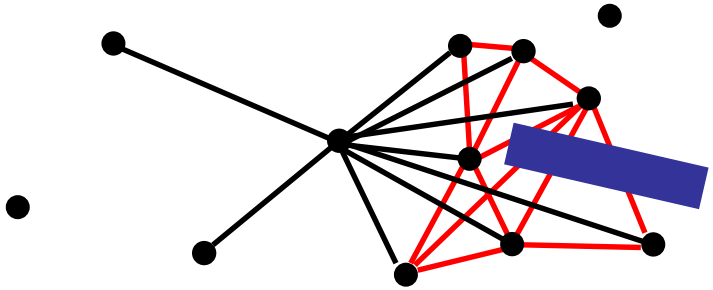





DON'T DISTURB MY CIRCLES.

Bounded Independence Graph (BIG)



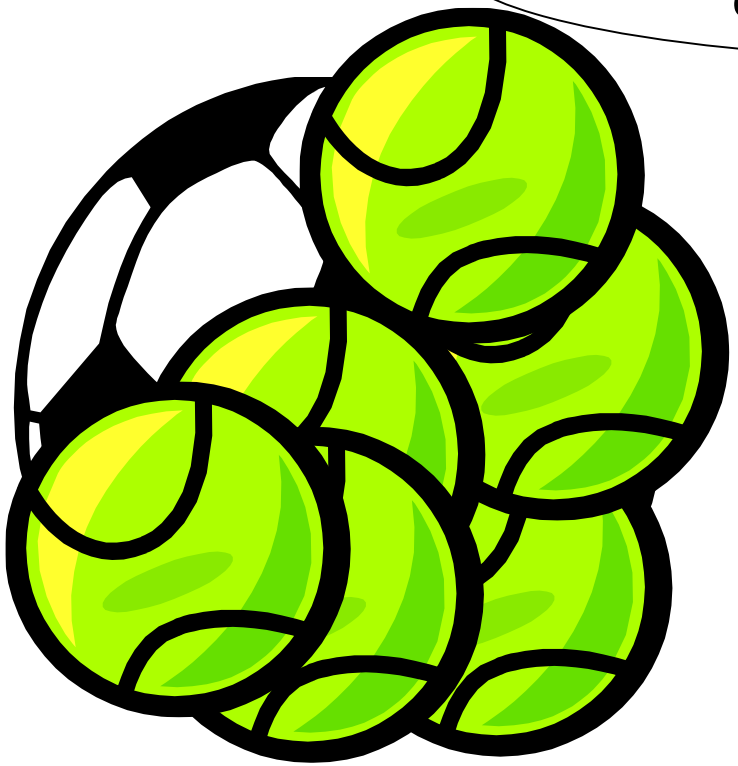


Size of any independent set grows polynomially with hop distance *r*

Unit Ball Graph (UBG)

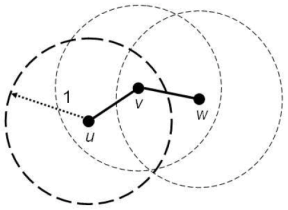
A *metric* with constant doubling dimension

you only need a constant number of balls of half the radius



Overview Wireless Connectivity Models

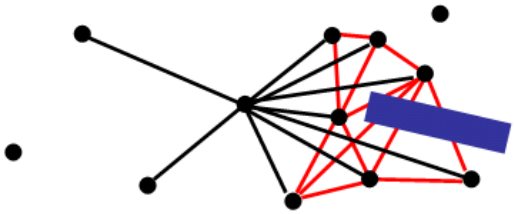
General Graph



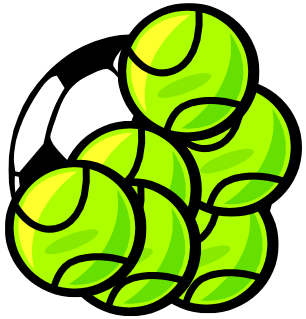
UDG

too pessimistic — **too optimistic**

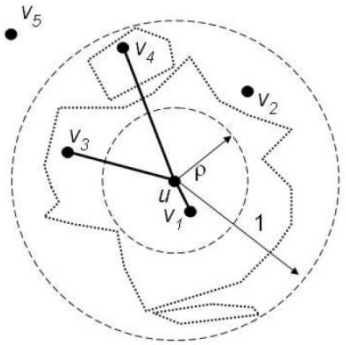
Bounded Independence



Unit Ball Graph

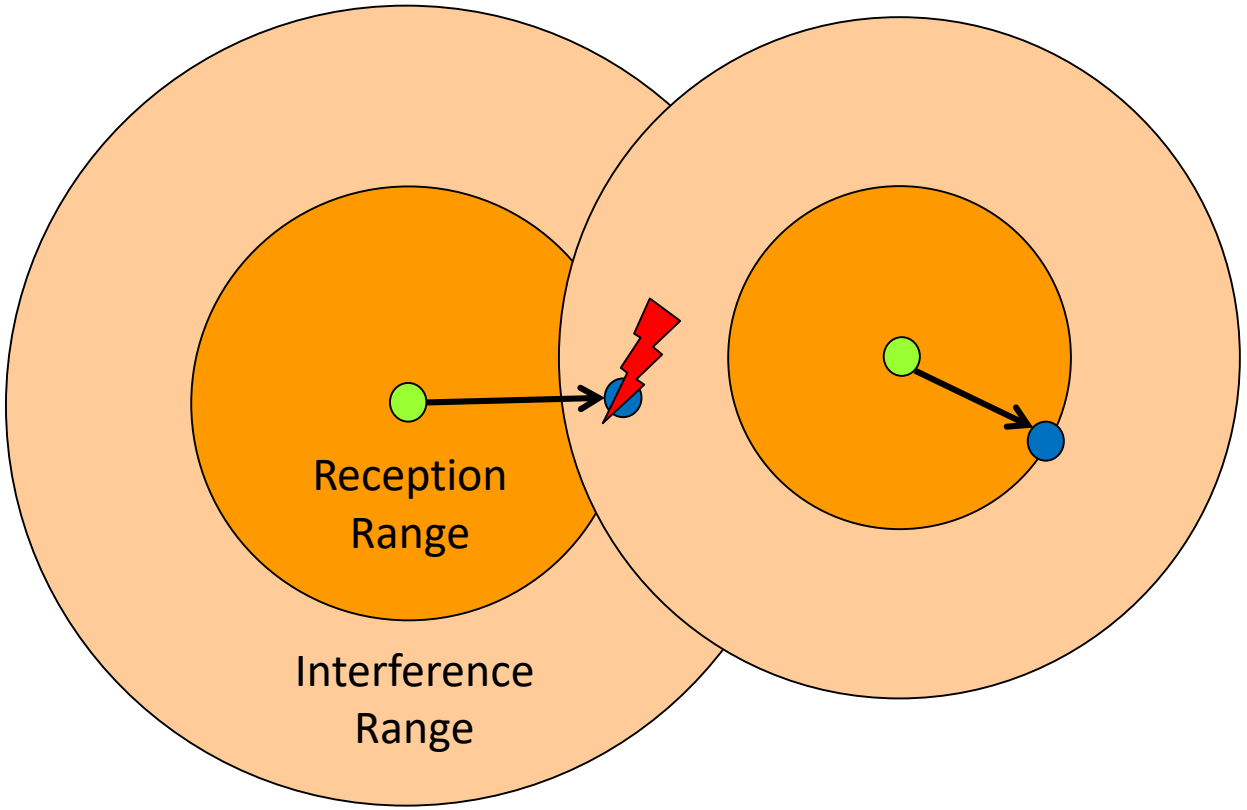


Quasi UDG

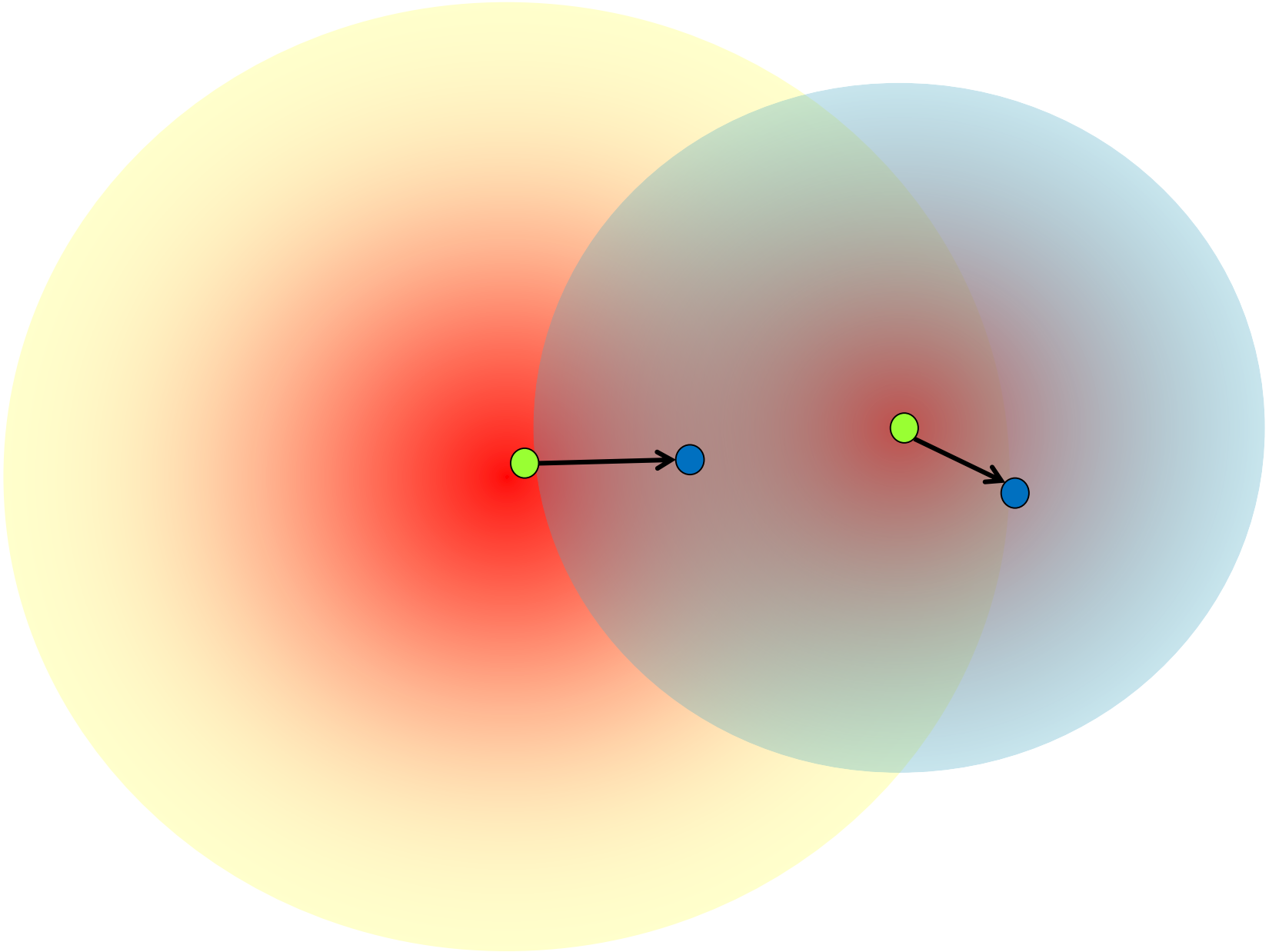


Wireless Beyond Connectivity

Protocol Model

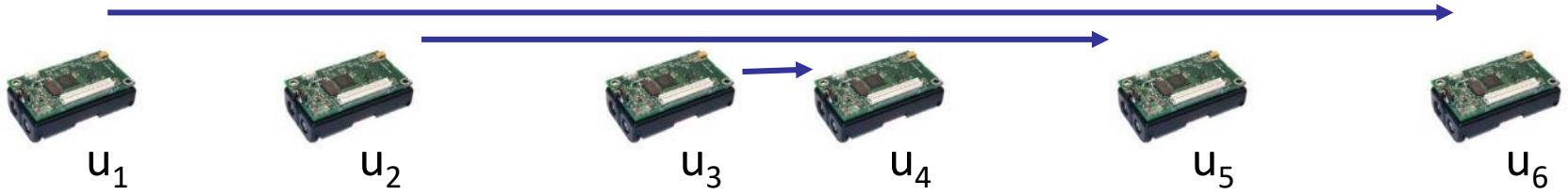


Physical (SINR) Model



From Audio to Wireless

… even with very simple hardware



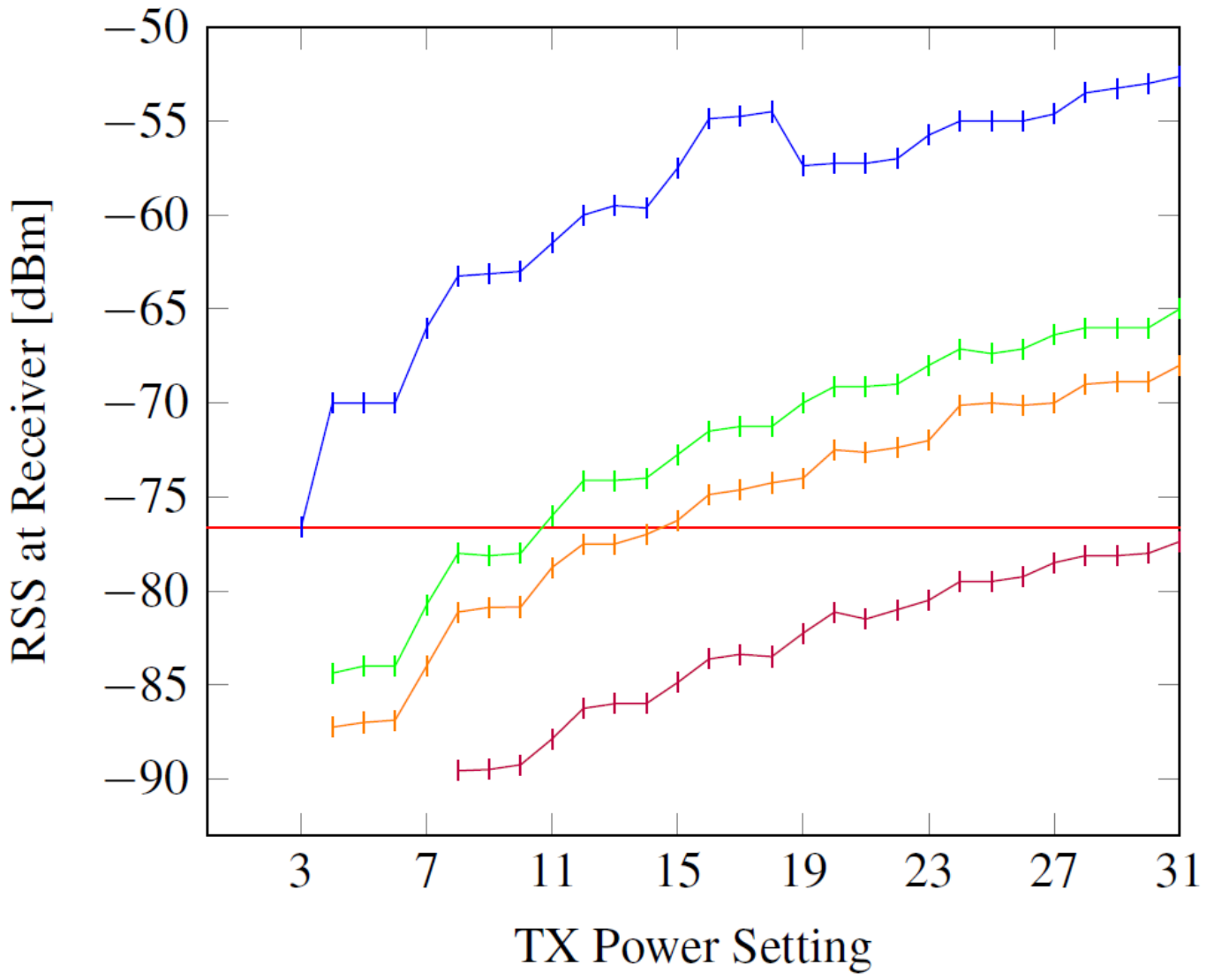
Time for transmitting 20‘000 packets:

	Time required	
	standard MAC	“SINR-MAC”
Node u_1	$721s$	$267s$
Node u_2	$778s$	$268s$
Node u_3	$780s$	$270s$

	Messages received	
	standard MAC	“SINR-MAC”
Node u_4	19999	19773
Node u_5	18784	18488
Node u_6	16519	19498

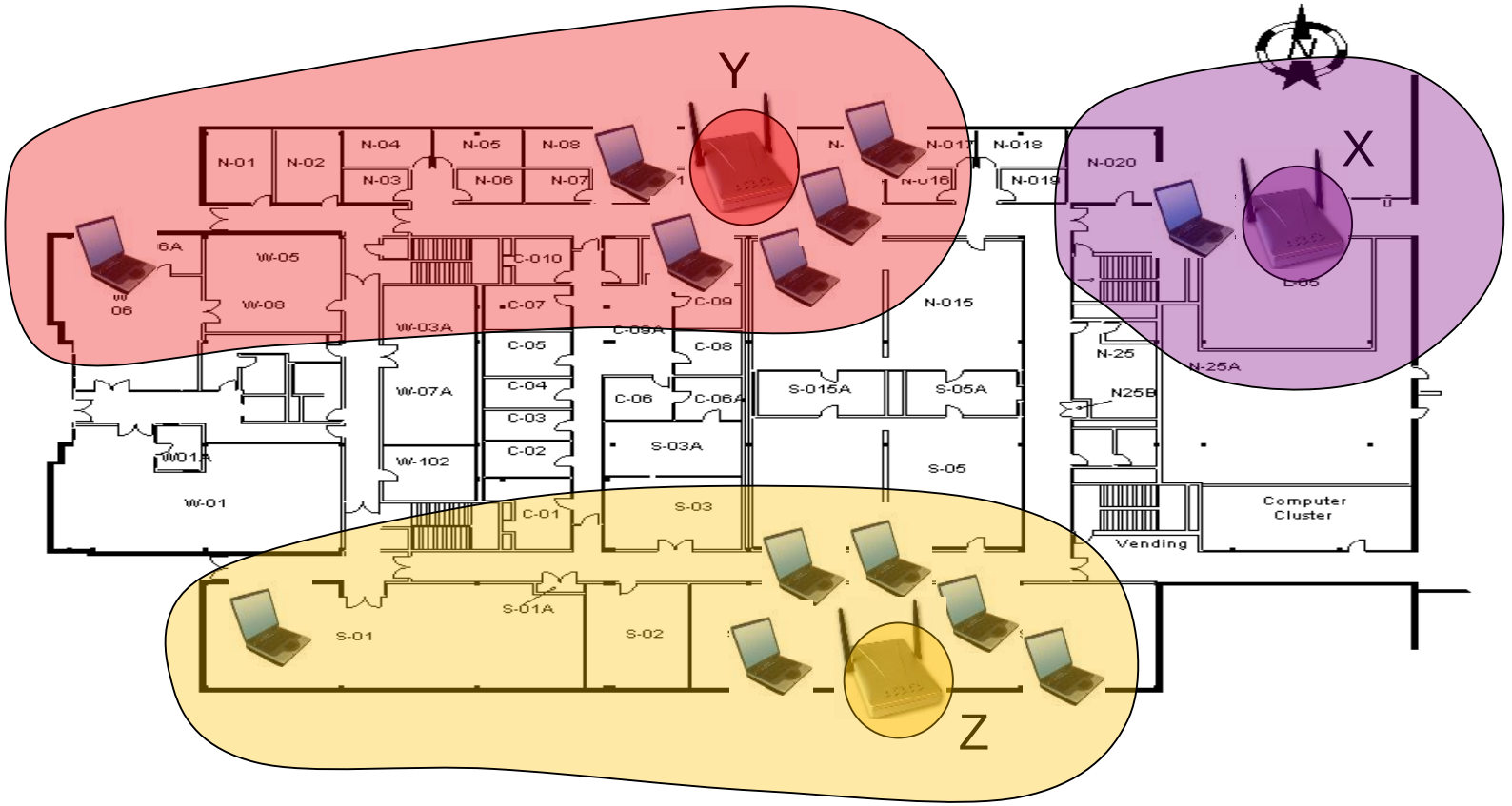
[Moscibroda et al., 2006]

The Power of Power Control

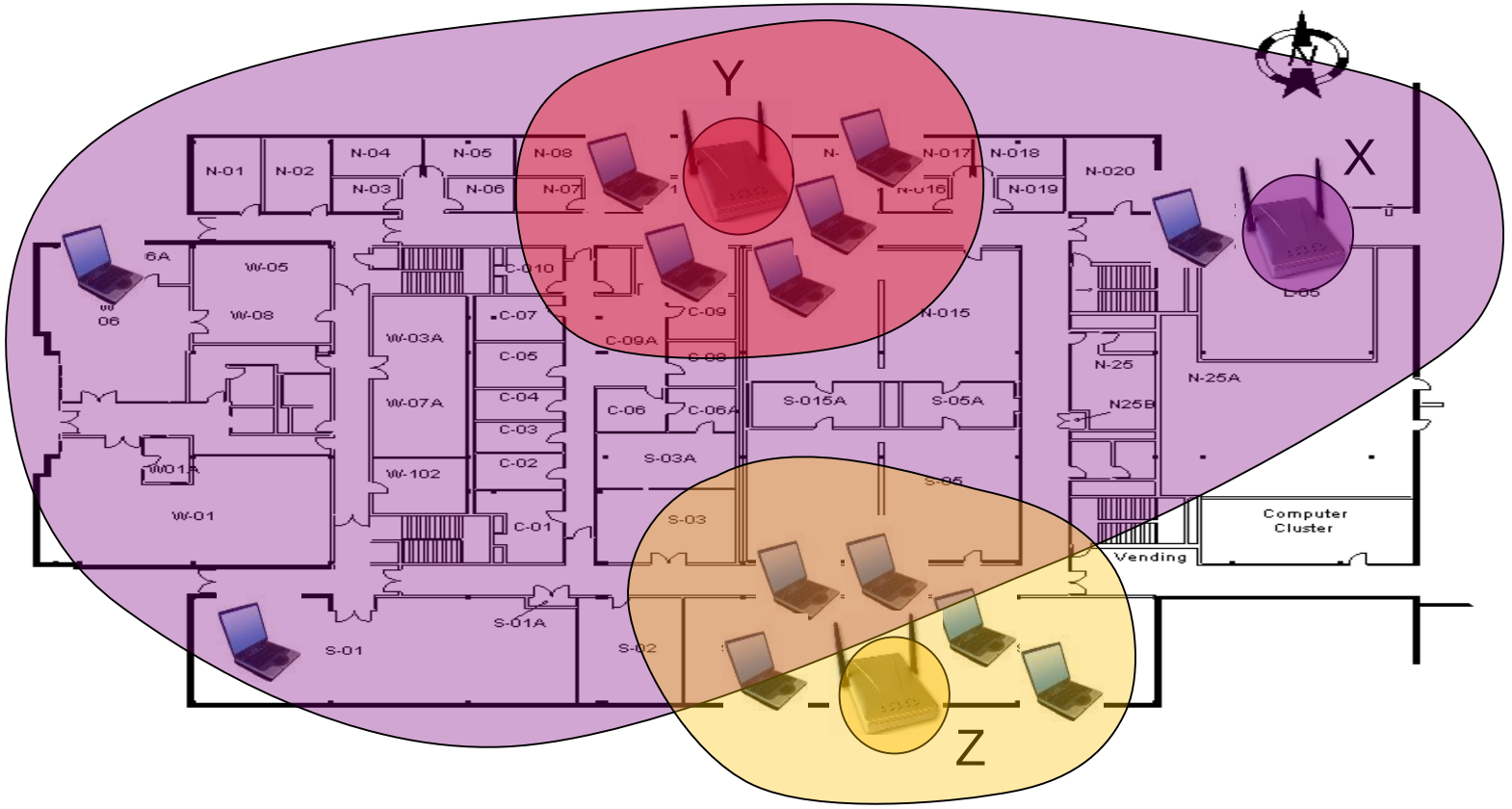


Improving Protocols with Graph Drawing

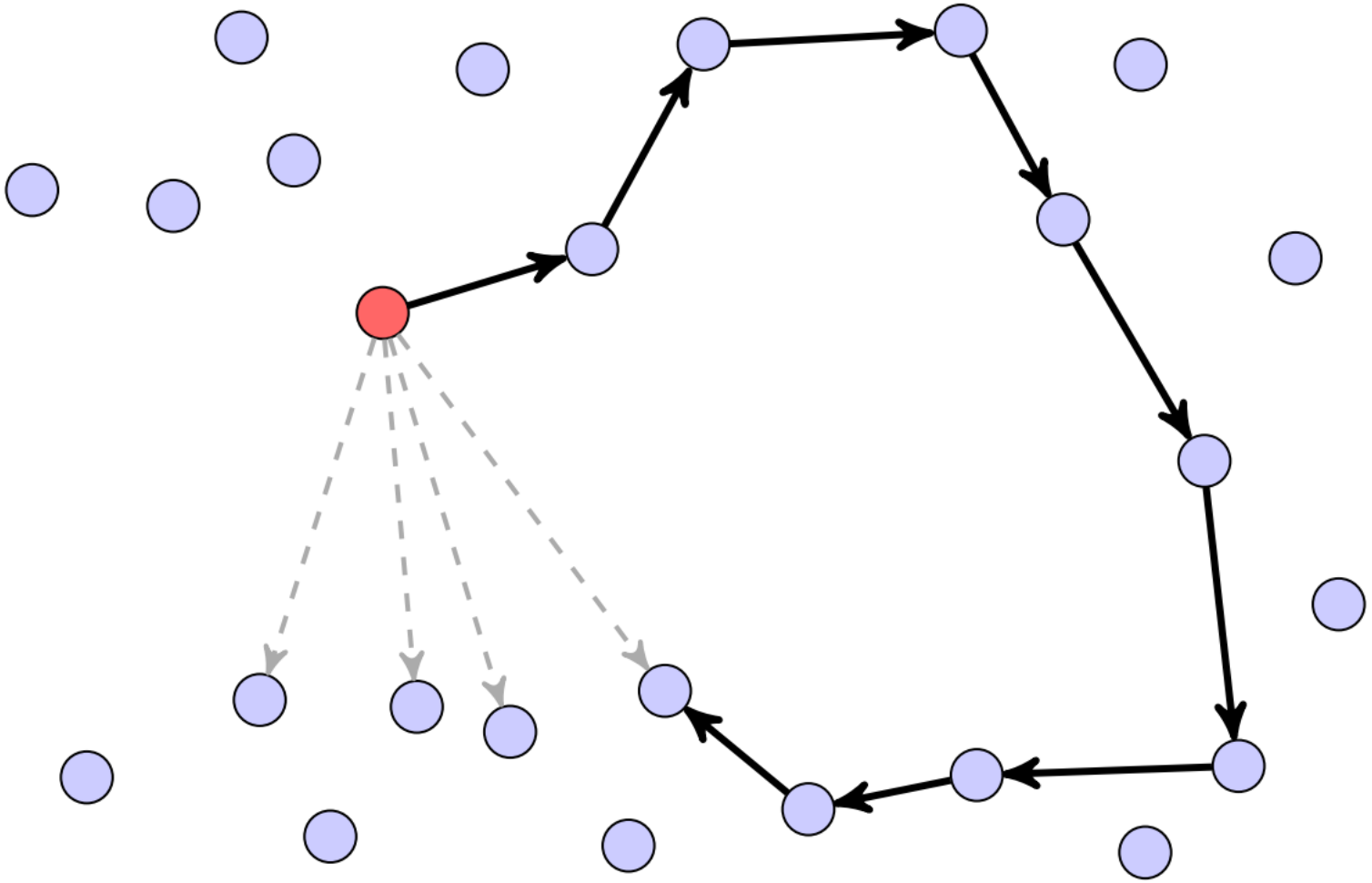
Possible Application: Hotspots in WLAN



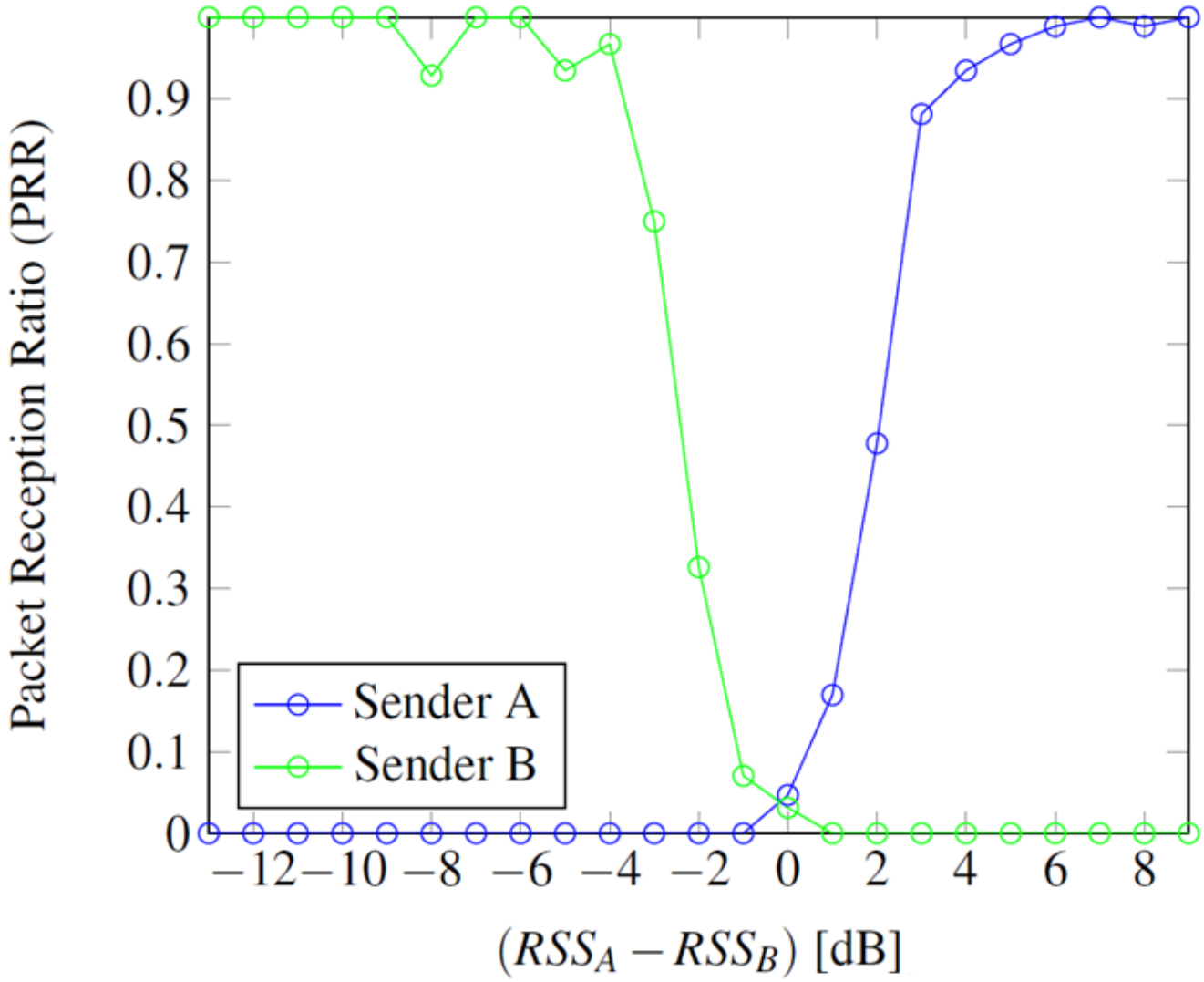
Possible Application: Hotspots in WLAN



MIMO et al.

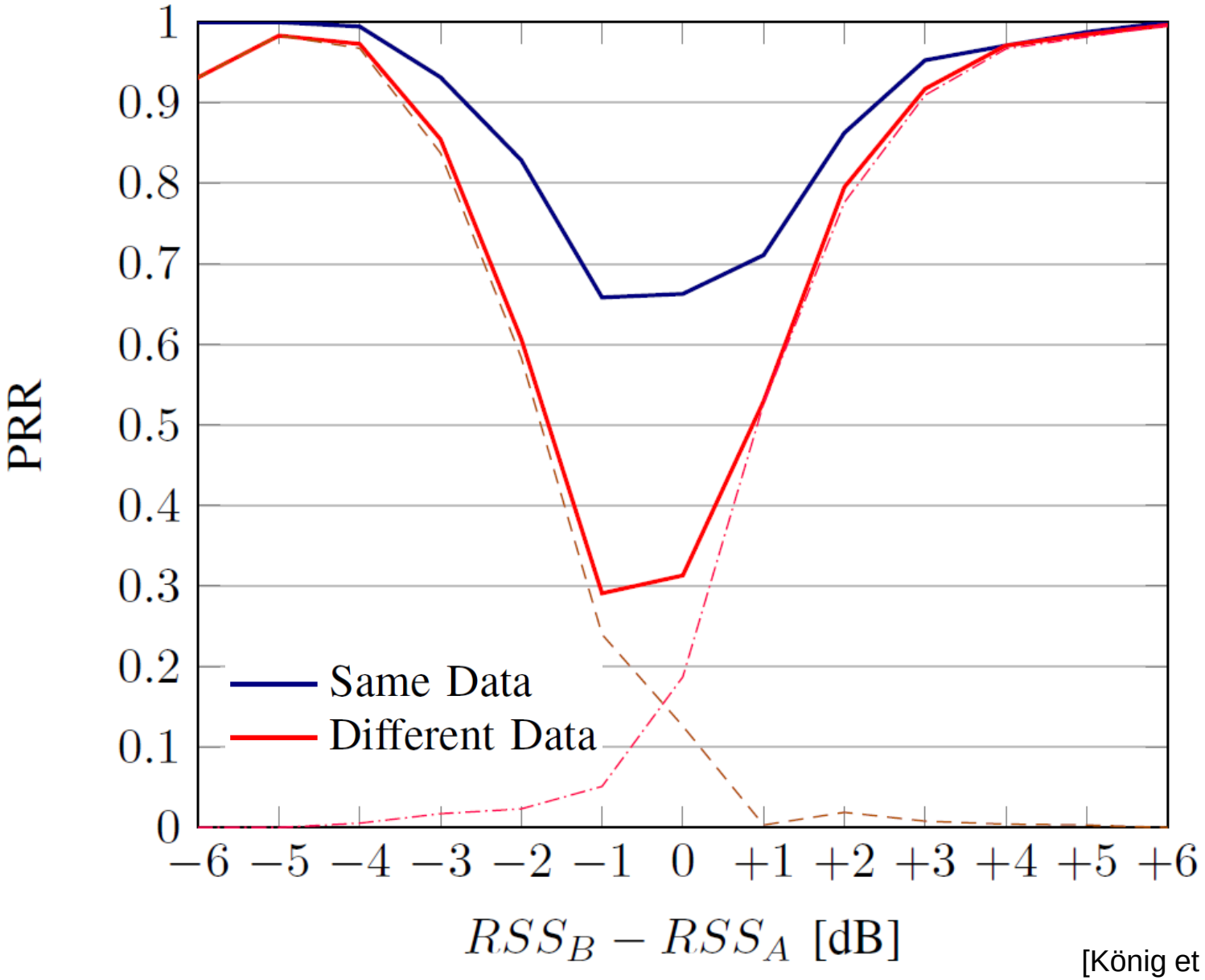


The Capture Effect – Power Difference



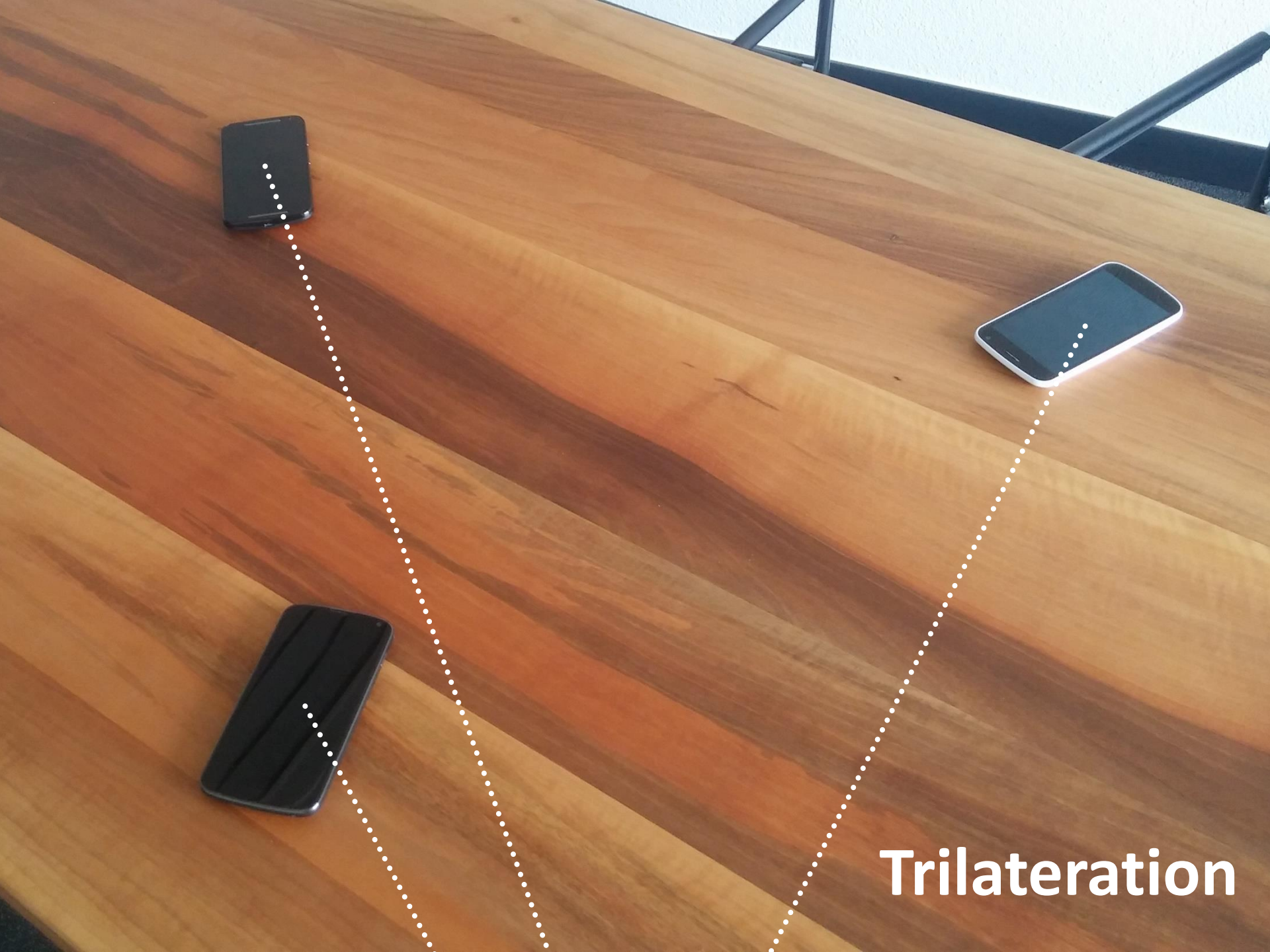
[König et al., 2016]

Two Transmitters, One Receiver

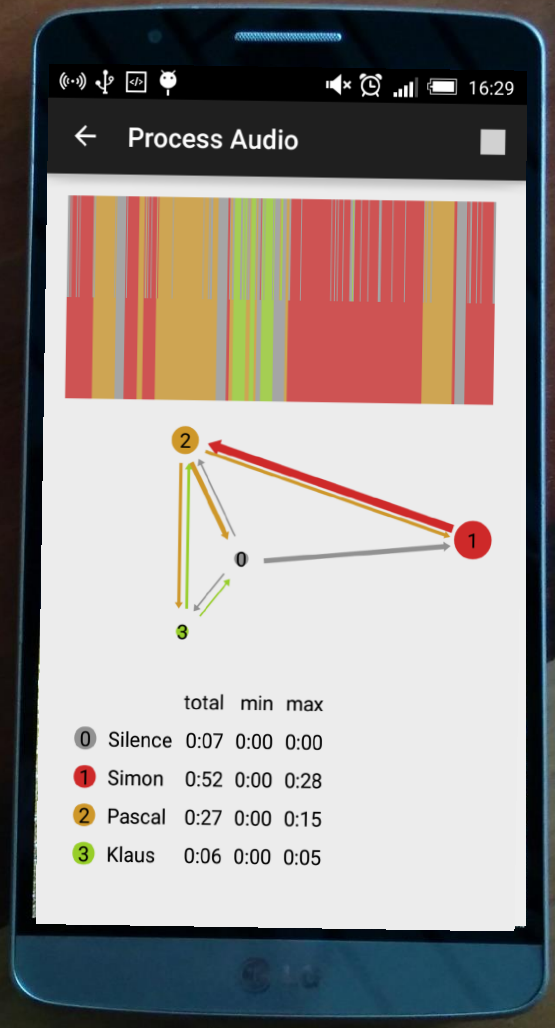


[König et al., 2016]

Using Distance Information


Trilateration

Disca: Distributed Discussion Statistics

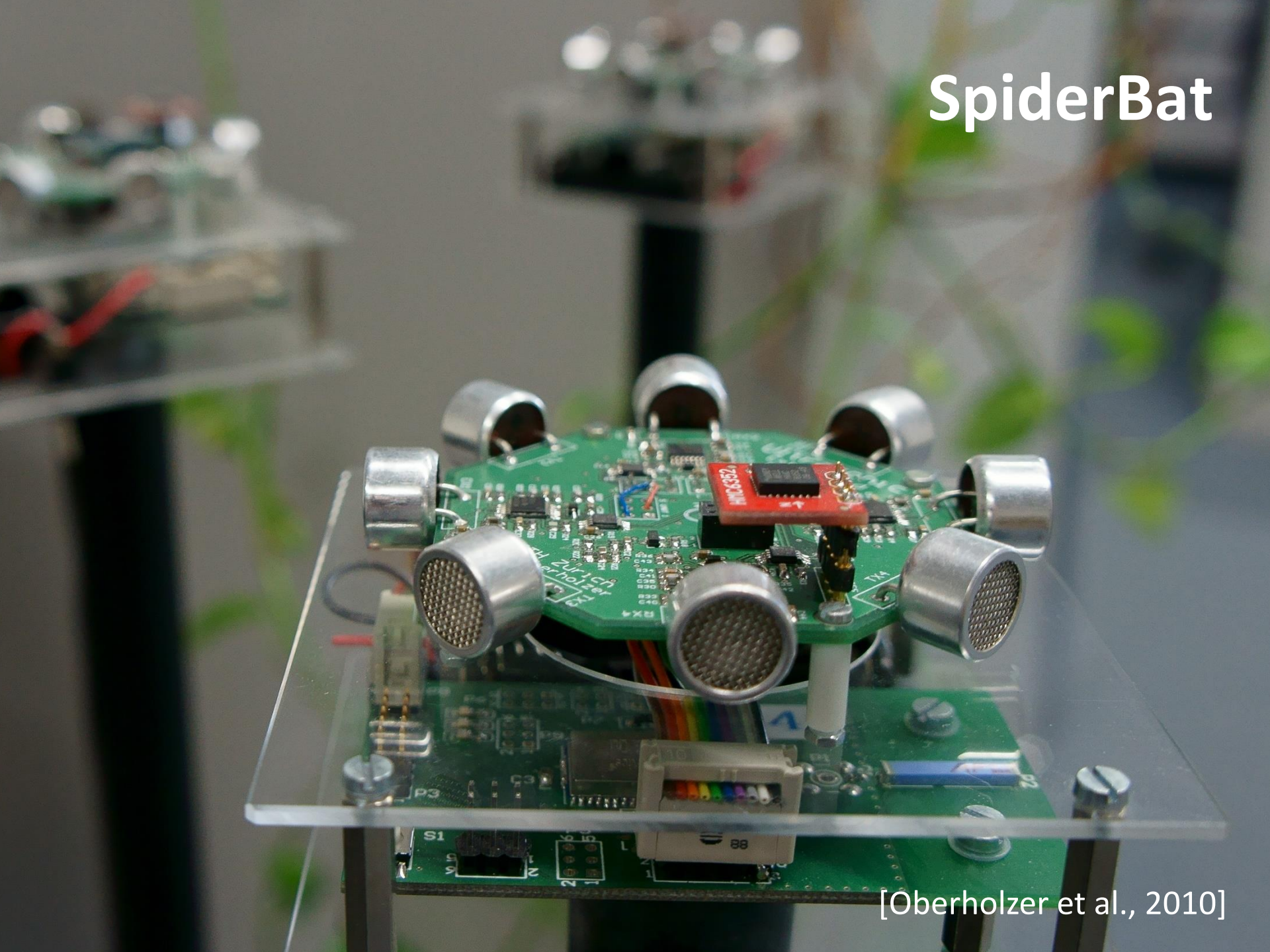


[Bissig et al., 2016]

Distance & Angle?

„People who are really serious about software should make their own hardware.”

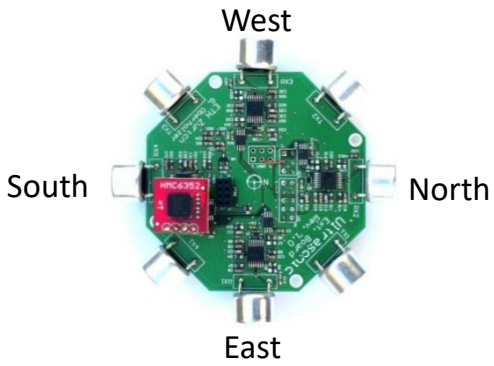
Alan Kay

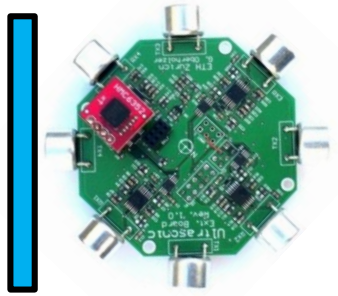

SpiderBat
[Oberholzer et al., 2010]

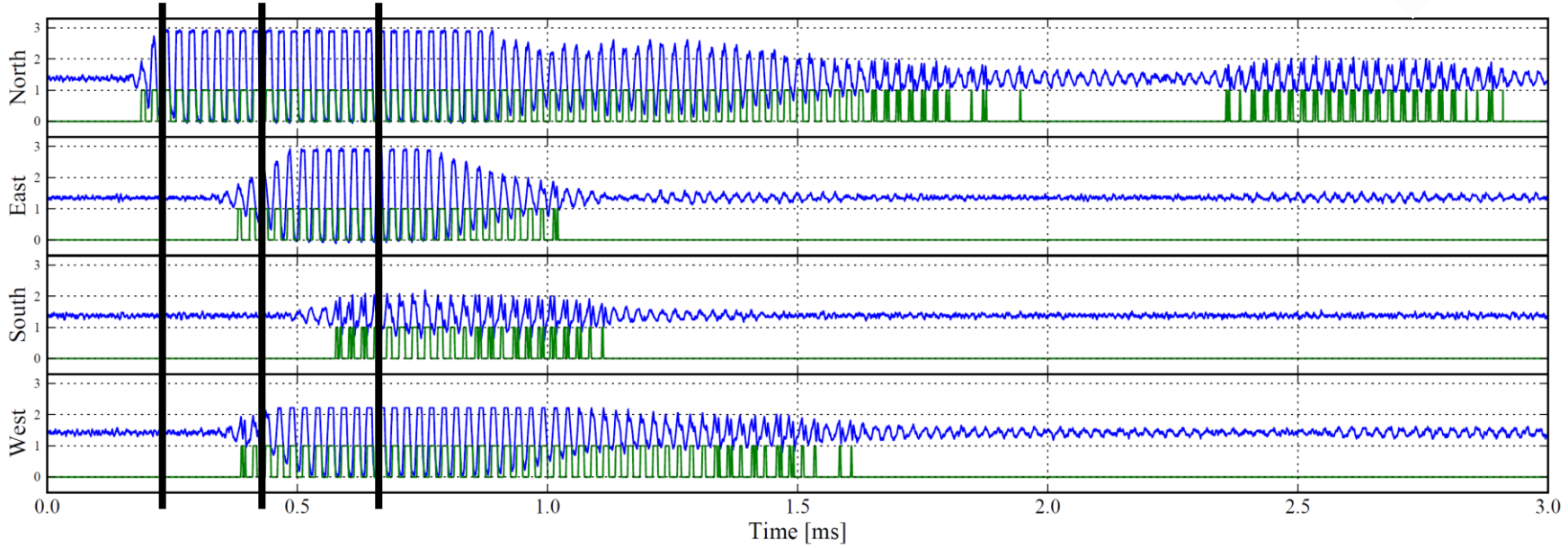
Angle-of-Arrival Measurements

Receiver

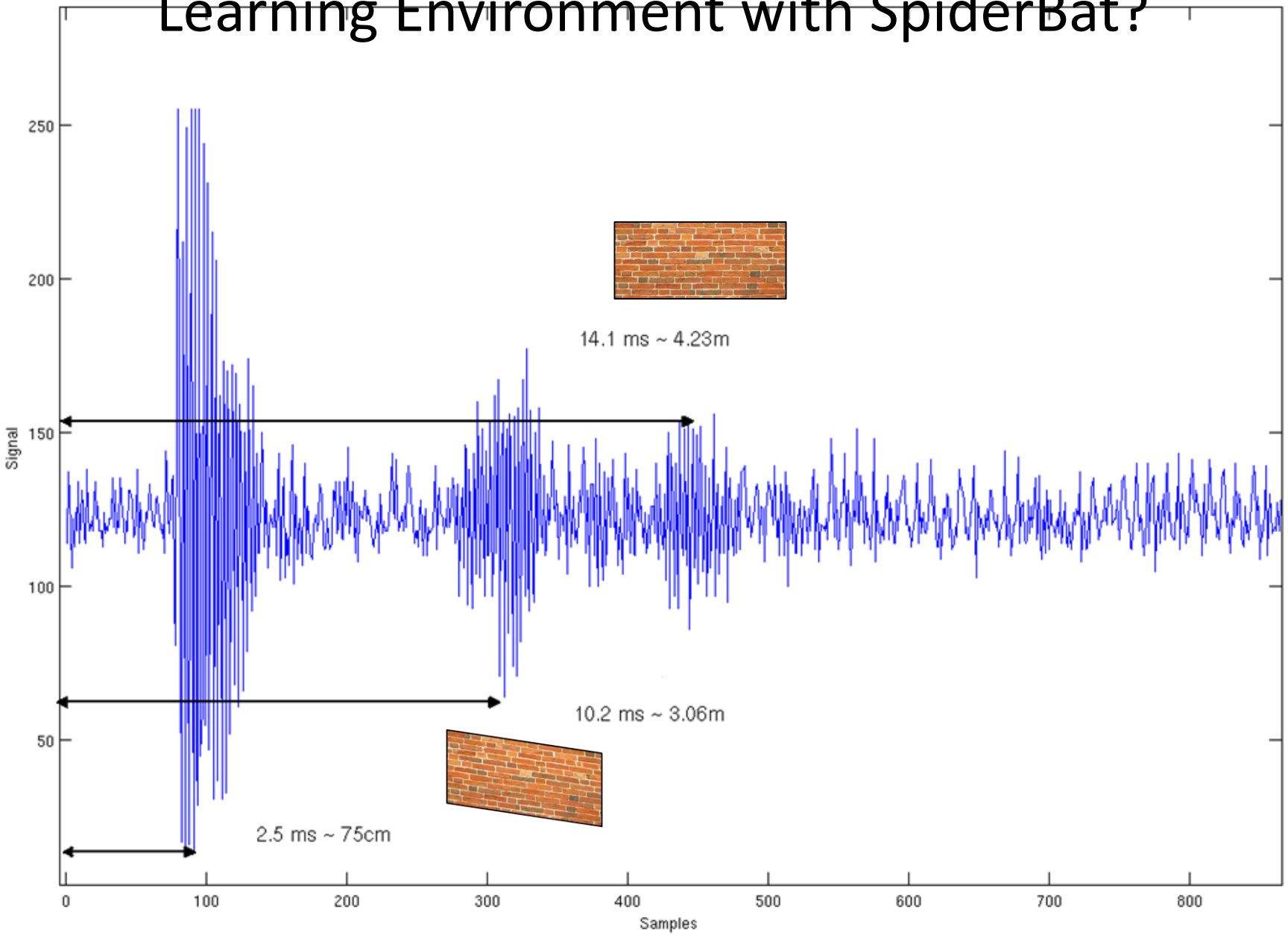
Sender

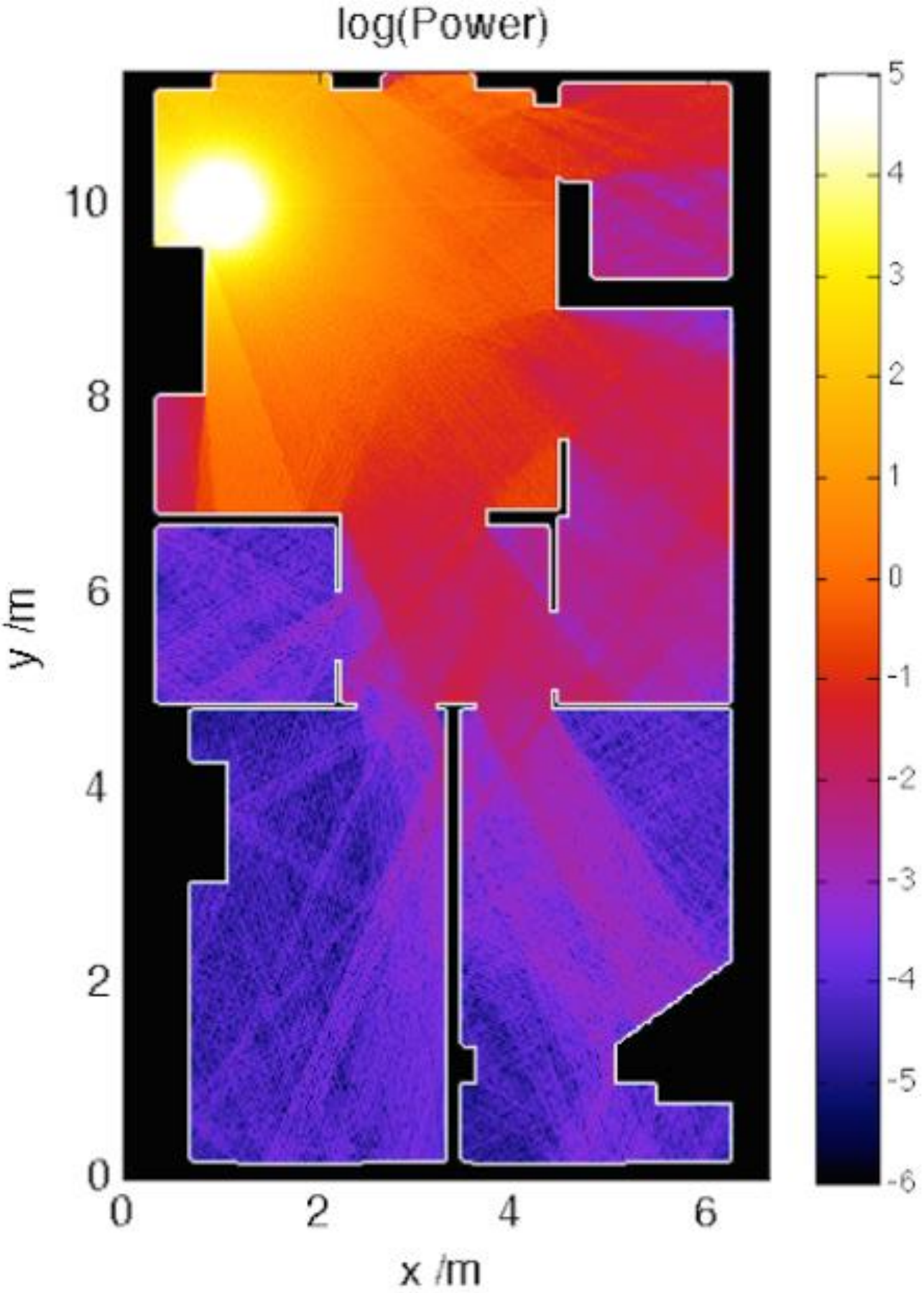






Learning Environment with SpiderBat?




log(Power)
10
8
6
4
2
0
y /m
0
2
4
6
x /m
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6

SpiderBat:
Iterative Art Gallery Problem?

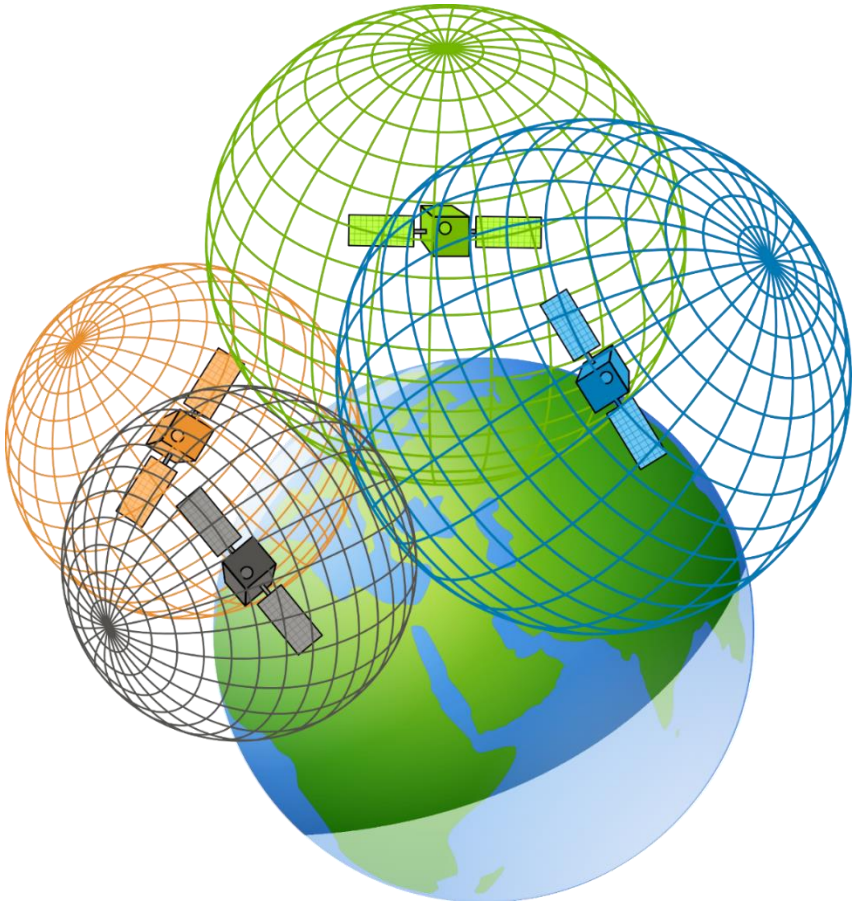
Mother of All Node→Coordinate Problems


GPS

Audio → Radio

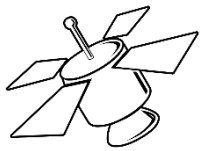
343 m/s 299 792 458 m/s

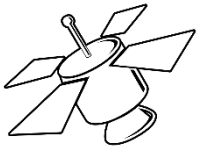
GPS Trilateration

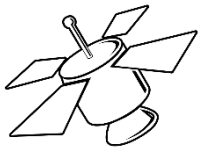


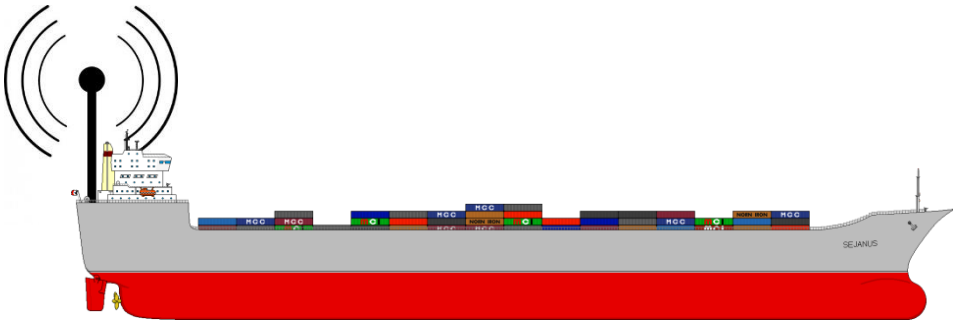
Least Squares to Compute Position & Time

Spoofing

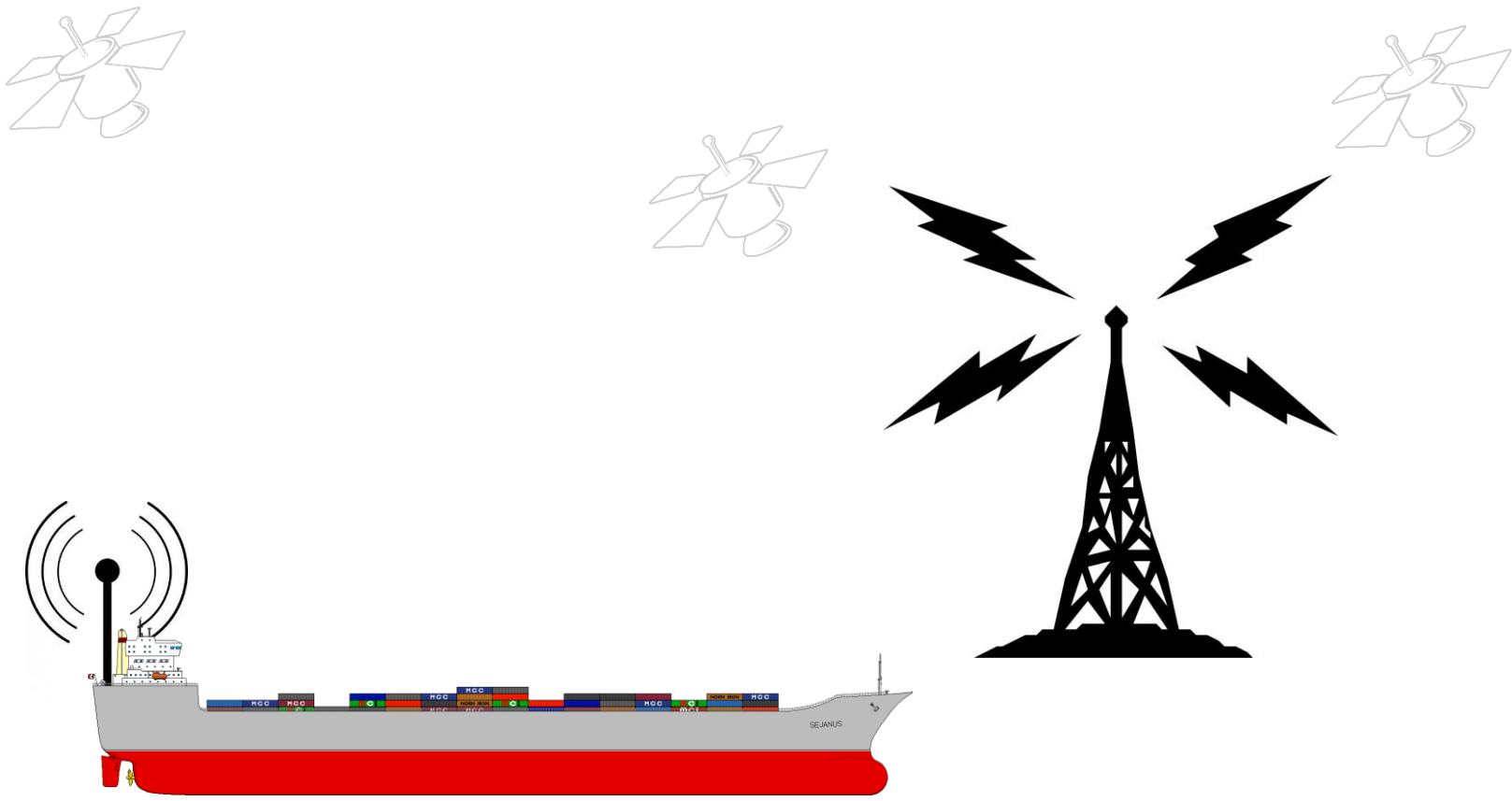




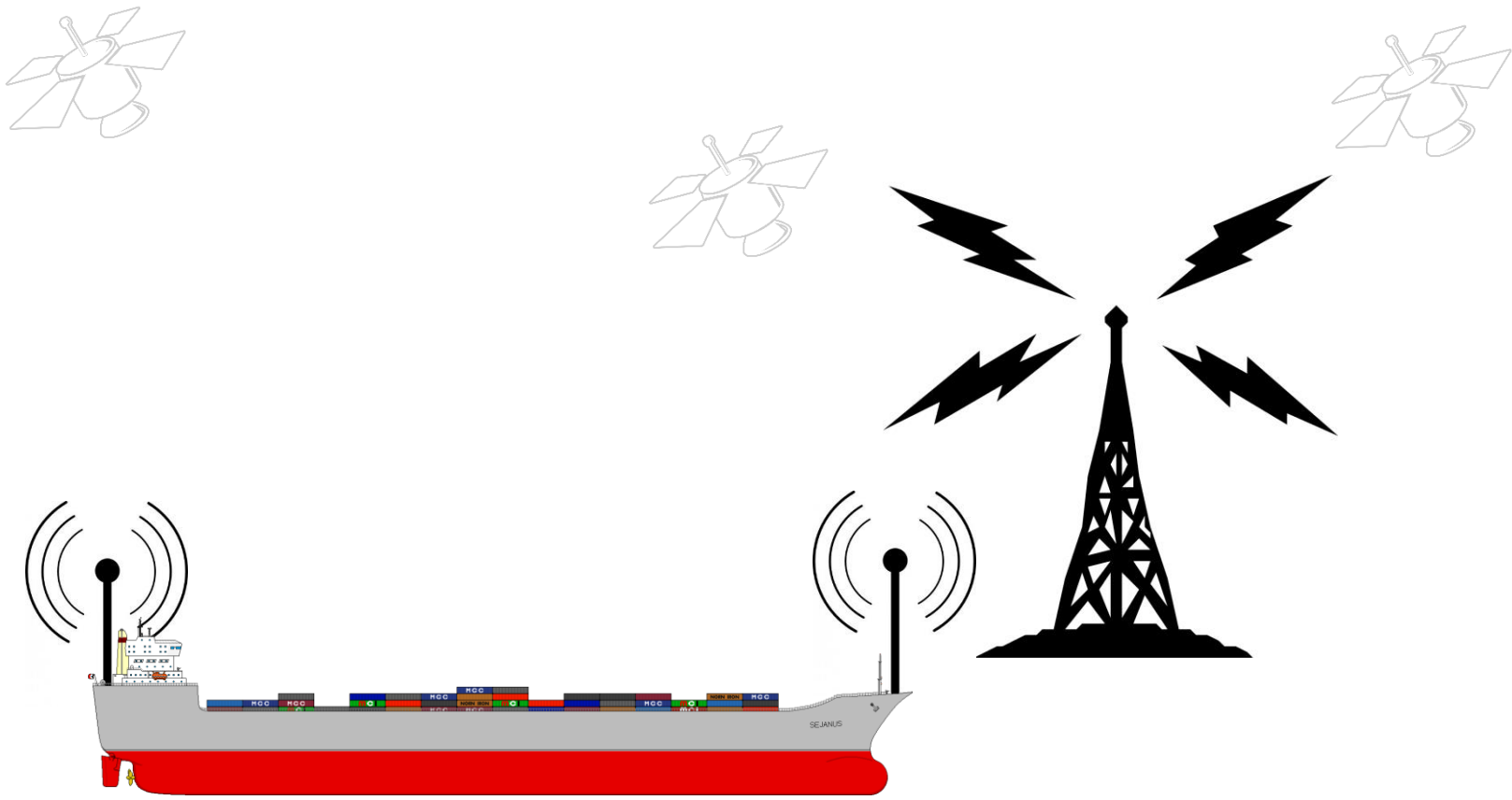




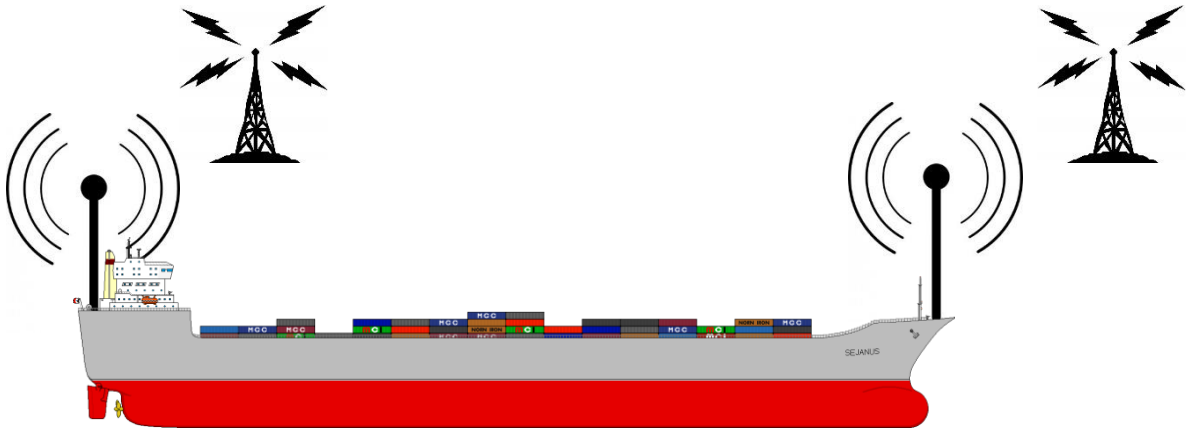
Spoofing



Spoofing

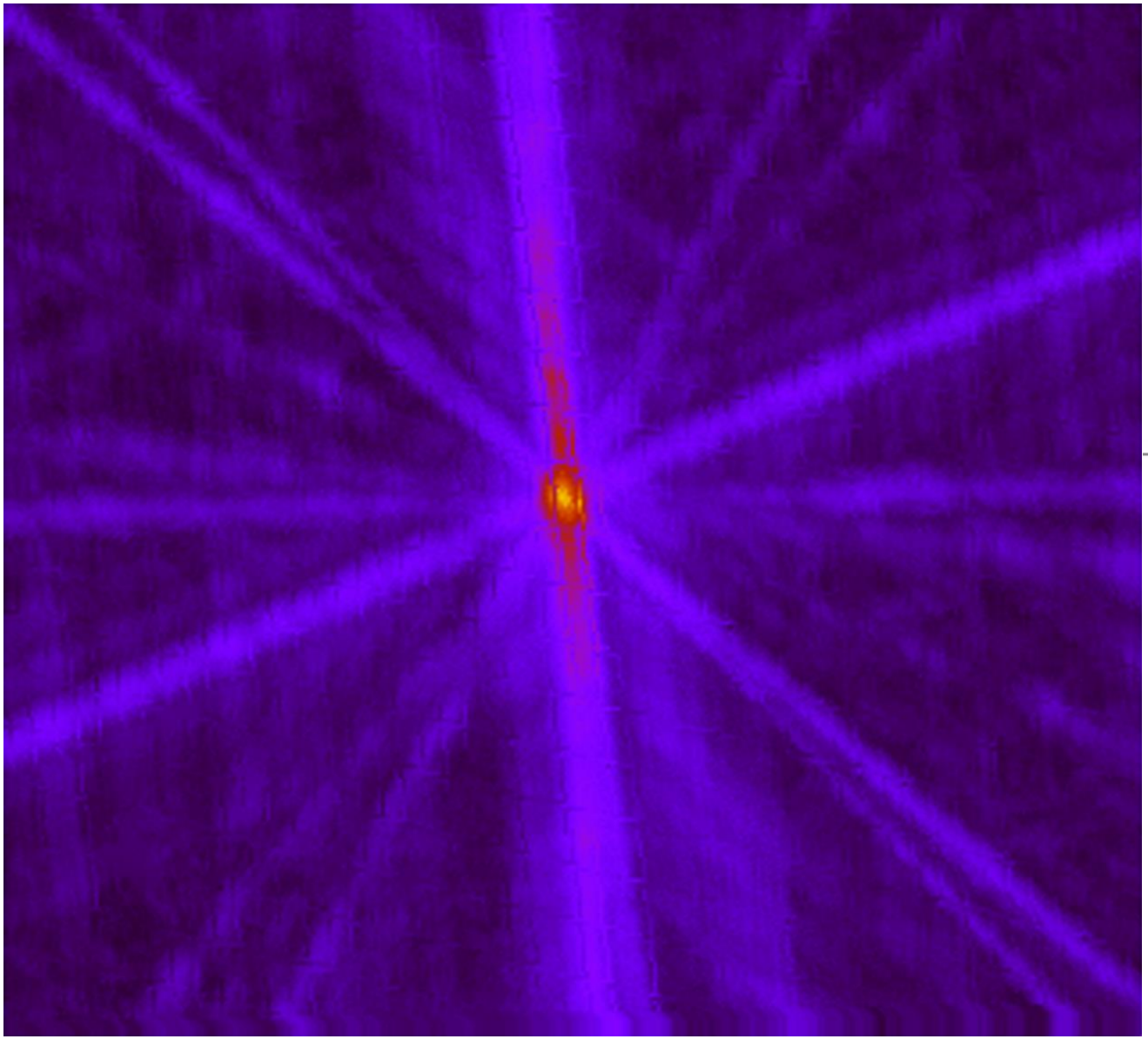


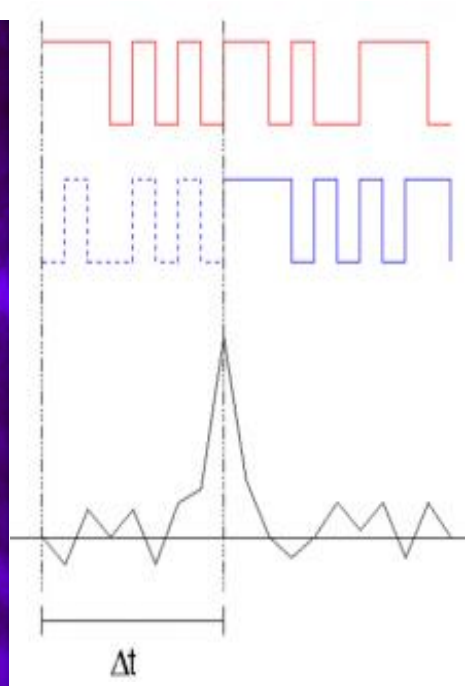
Spoofing

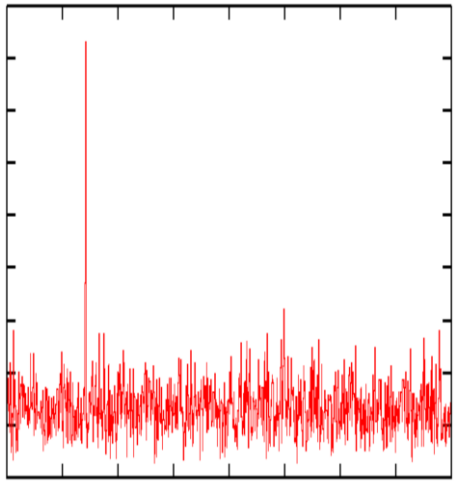


How Expensive is Spoofing?

Alternative Approach: Collective Detection

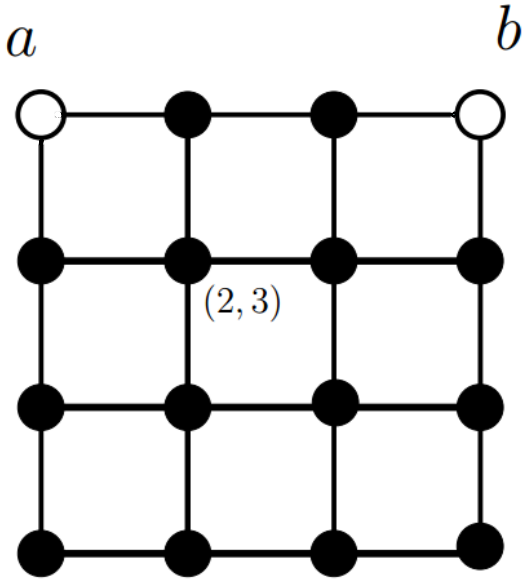


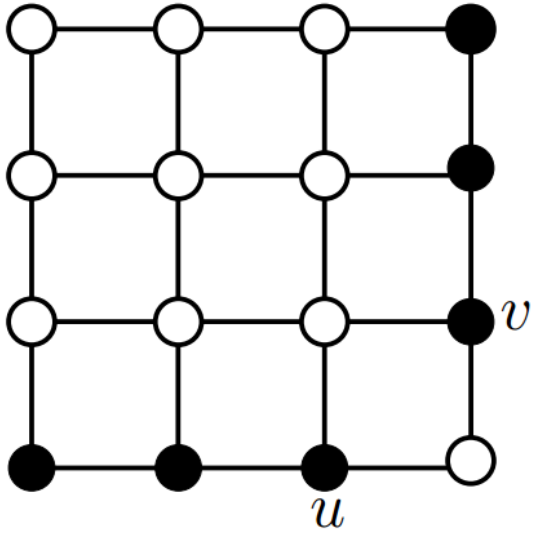




Drawing → Routing

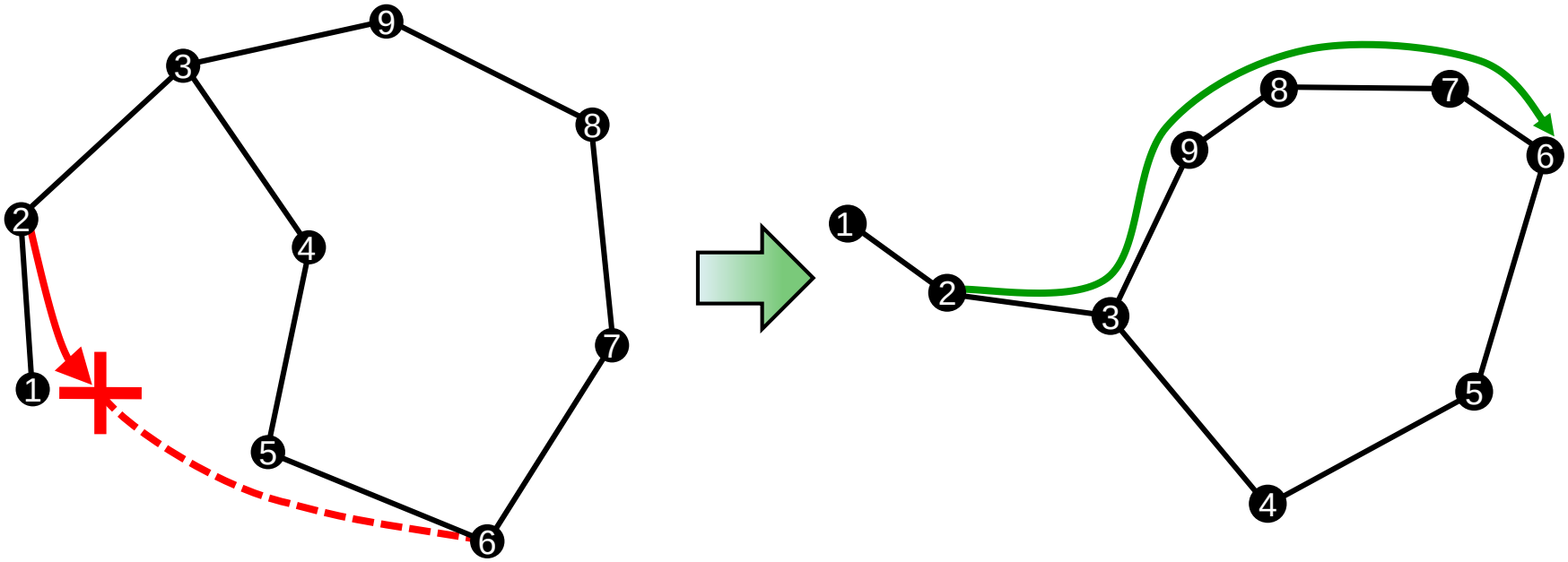
Anchor-Based Routing





[W et al., 2005]

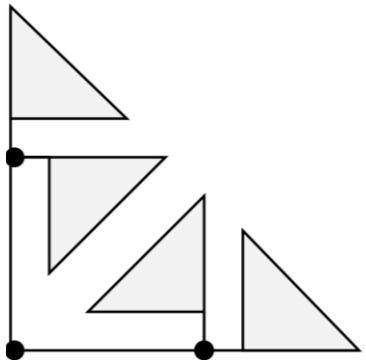
Greedy Geometric Routing

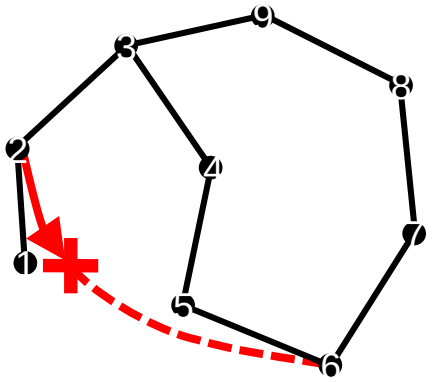


Related: self-approaching graph drawings, increasing-chord drawings, monotone drawings, hyperbolic geometry, …

[Flury et al., 2009]

Summary



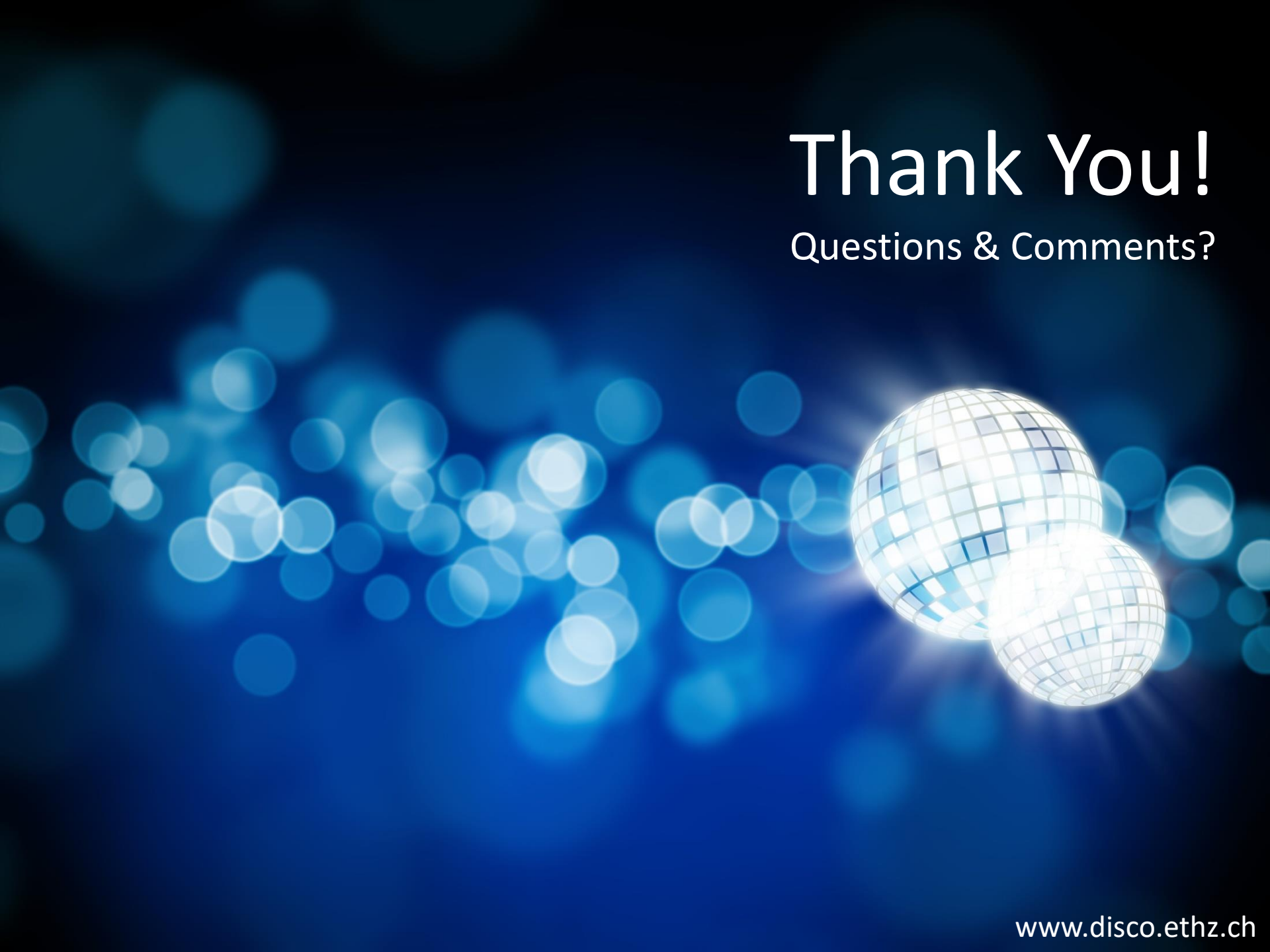


Open Problem

Draw wireless networks modeled by UDG, QUDG, BIG, UBG by using connectivitiy, interference, distance, angle, or multipath information to understand which node is which, or for better protocols (routing, media access).

Thank You!

Questions & Comments?



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