Topology Control, Interference and Collaboration in Wireless Ad-Hoc and Sensor Networks

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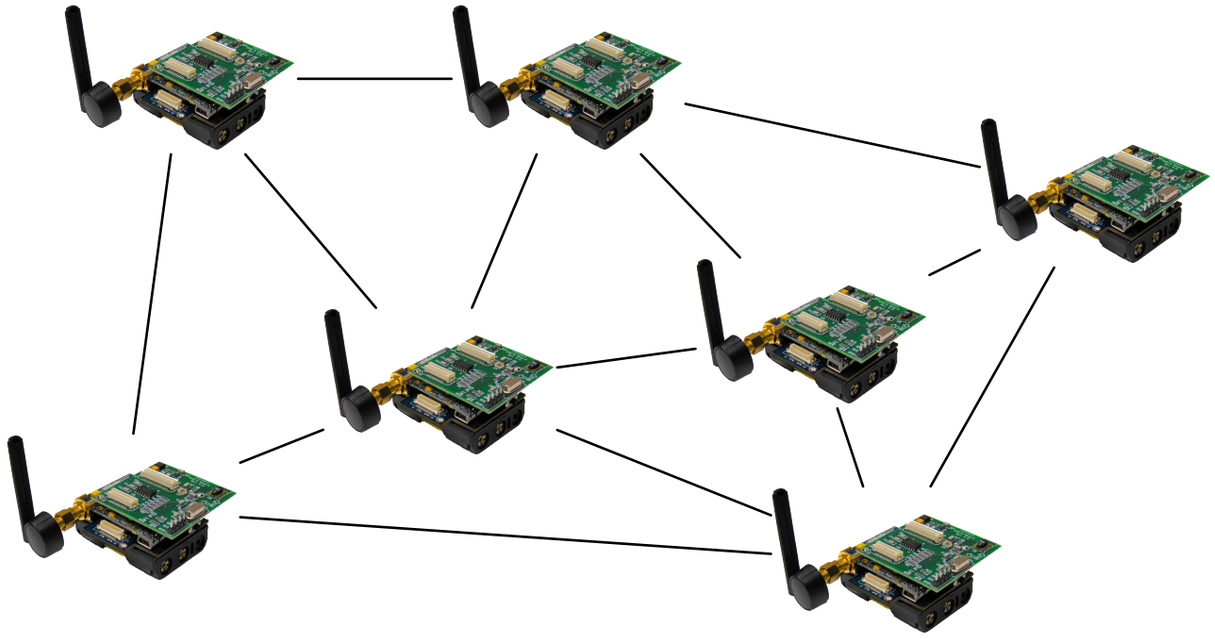
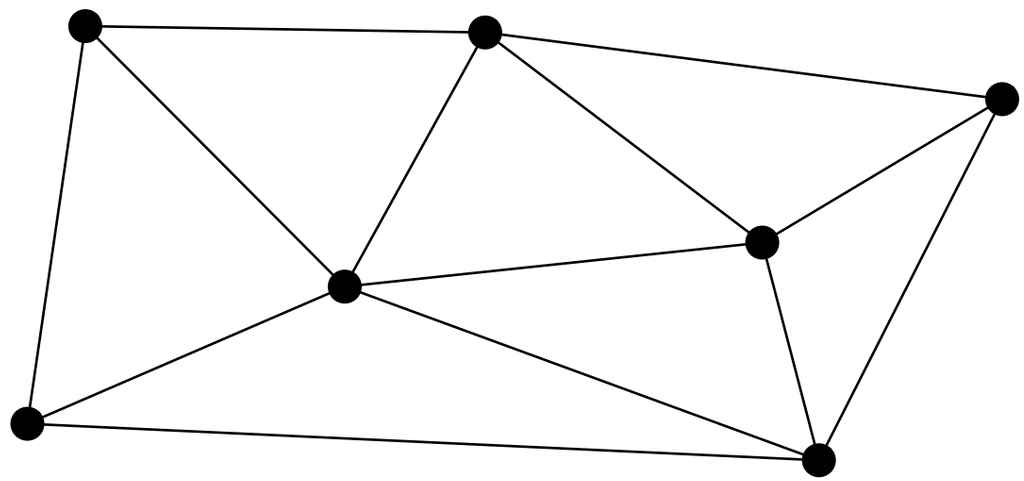
comments on my thesis submitted
in partial fulfillment of the requirements
for obtaining the nickname Dr. Fly

Ad-Hoc / Sensor Module

- small devices
- powered by batteries
- low computational power
- low transmission power
- small antenna
- low and small everything else
- self configurable into scalable networks

The Network



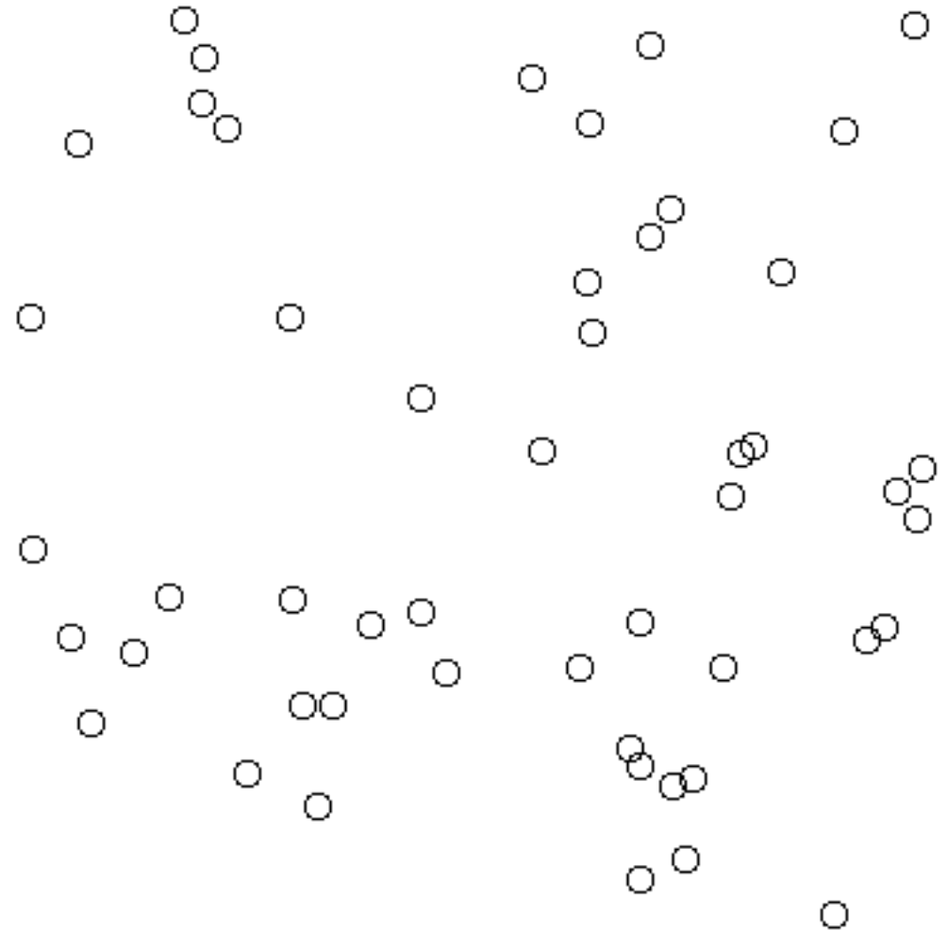


The Problems

- Many, horribly many
- We attacked two:
  - Interference and Topology Control
  - Long distance connections
- Allow me to show them to you

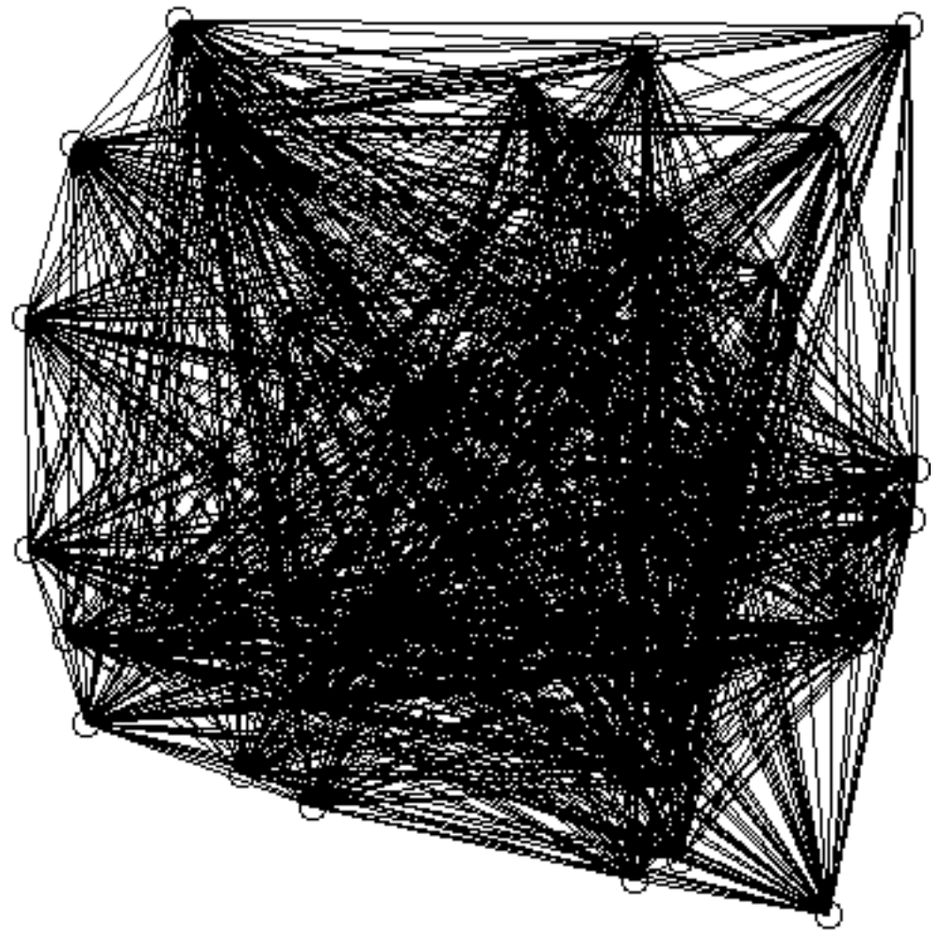
Topology Control

- Let us consider 50 modules, randomly placed and their radio connections between themselves



Topology Control

- Let us consider 50 modules, randomly placed and their radio connections between themselves
- That is 50*49/2=1225 connections

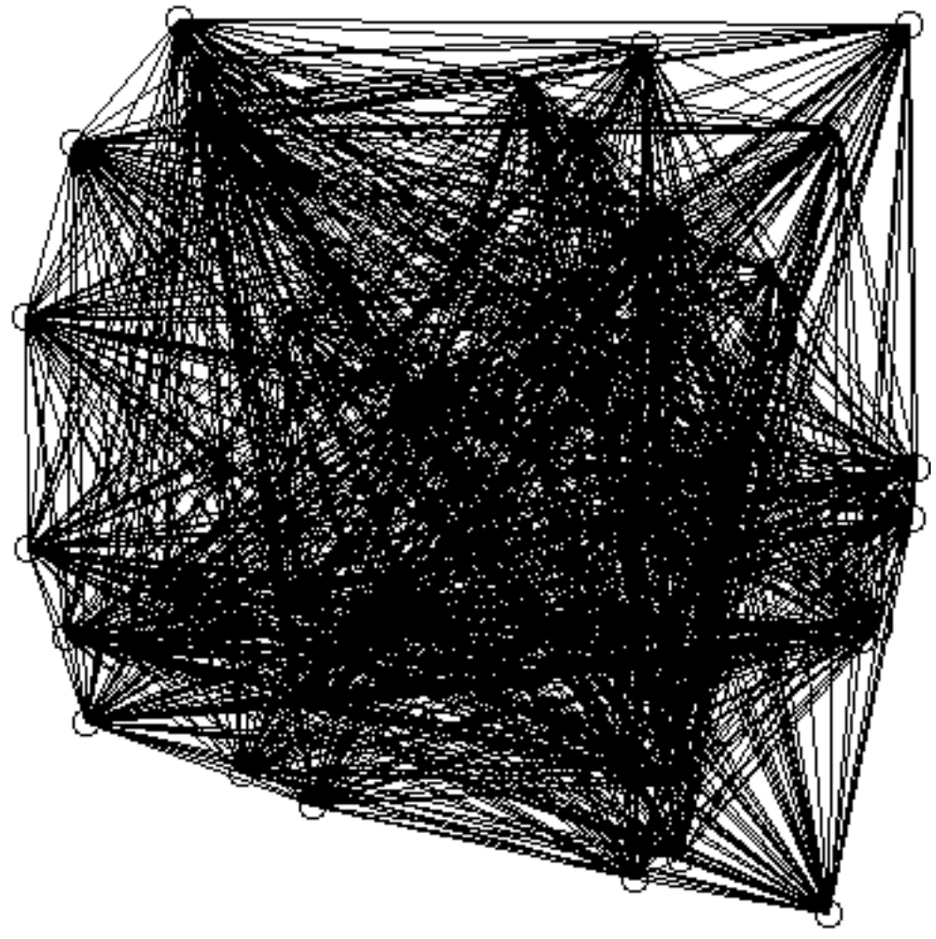


Too Many Connections

- Theoretically good because we have many alternative paths
- In radio this will never work because all you get is just interference

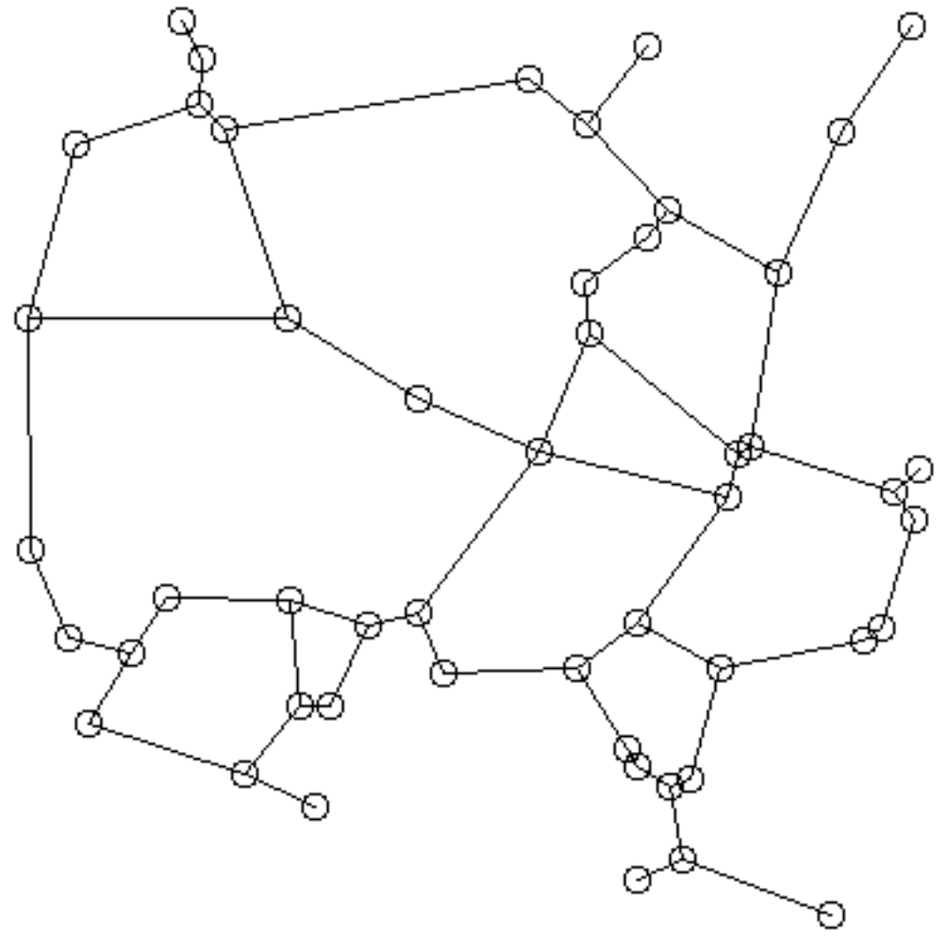
Topology Control

- To get from this



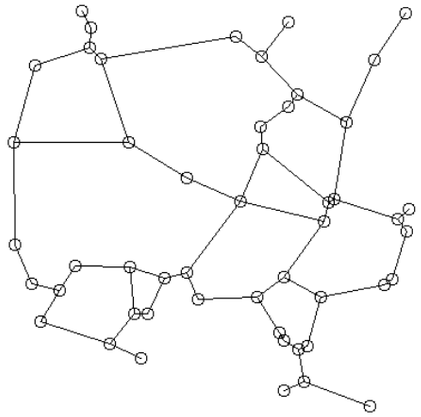
Topology Control

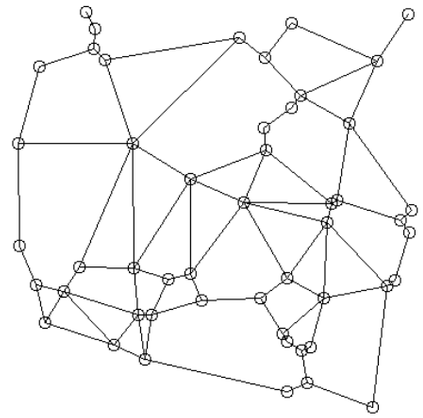
- To this

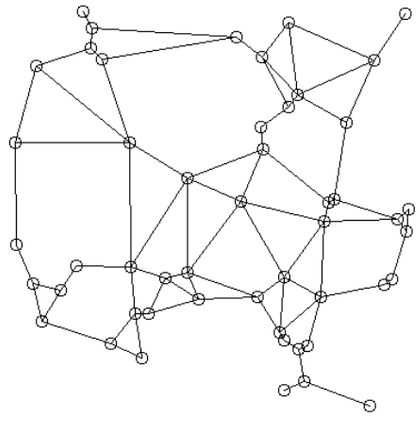


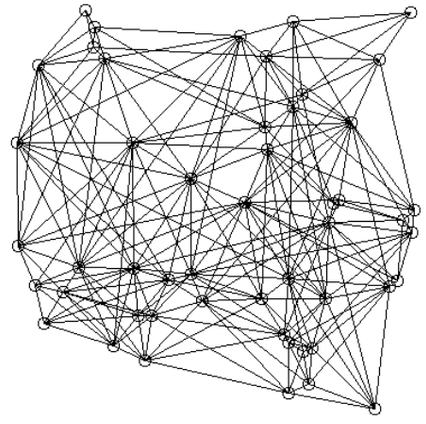
Topology Control

- Or any of this



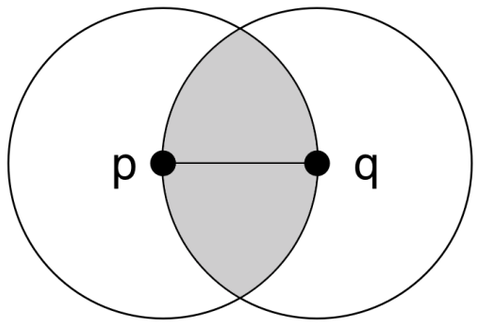


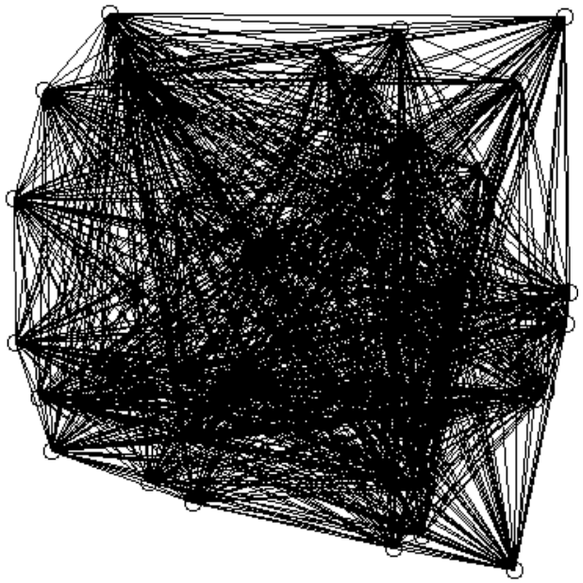


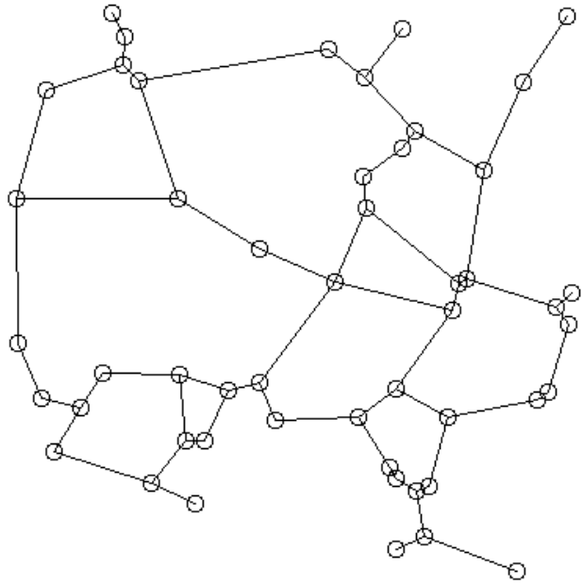


How?

- One idea is called RNG (Relative Neighborhood Graph)



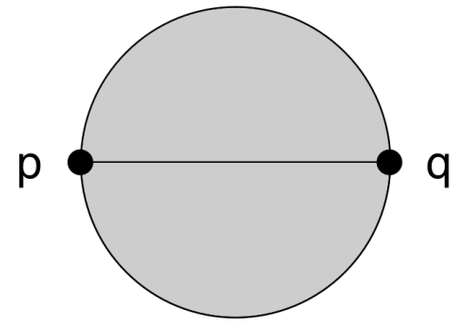


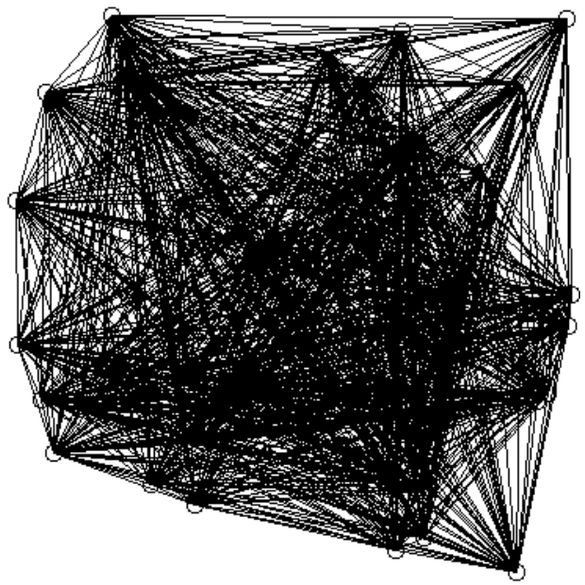


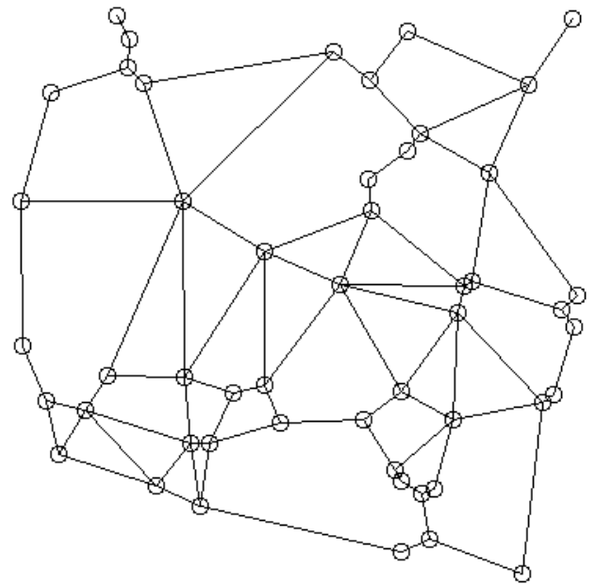
- Actually it is not math but still networking and energy

Another Idea

- One idea is called GG (Gabriel Graph)

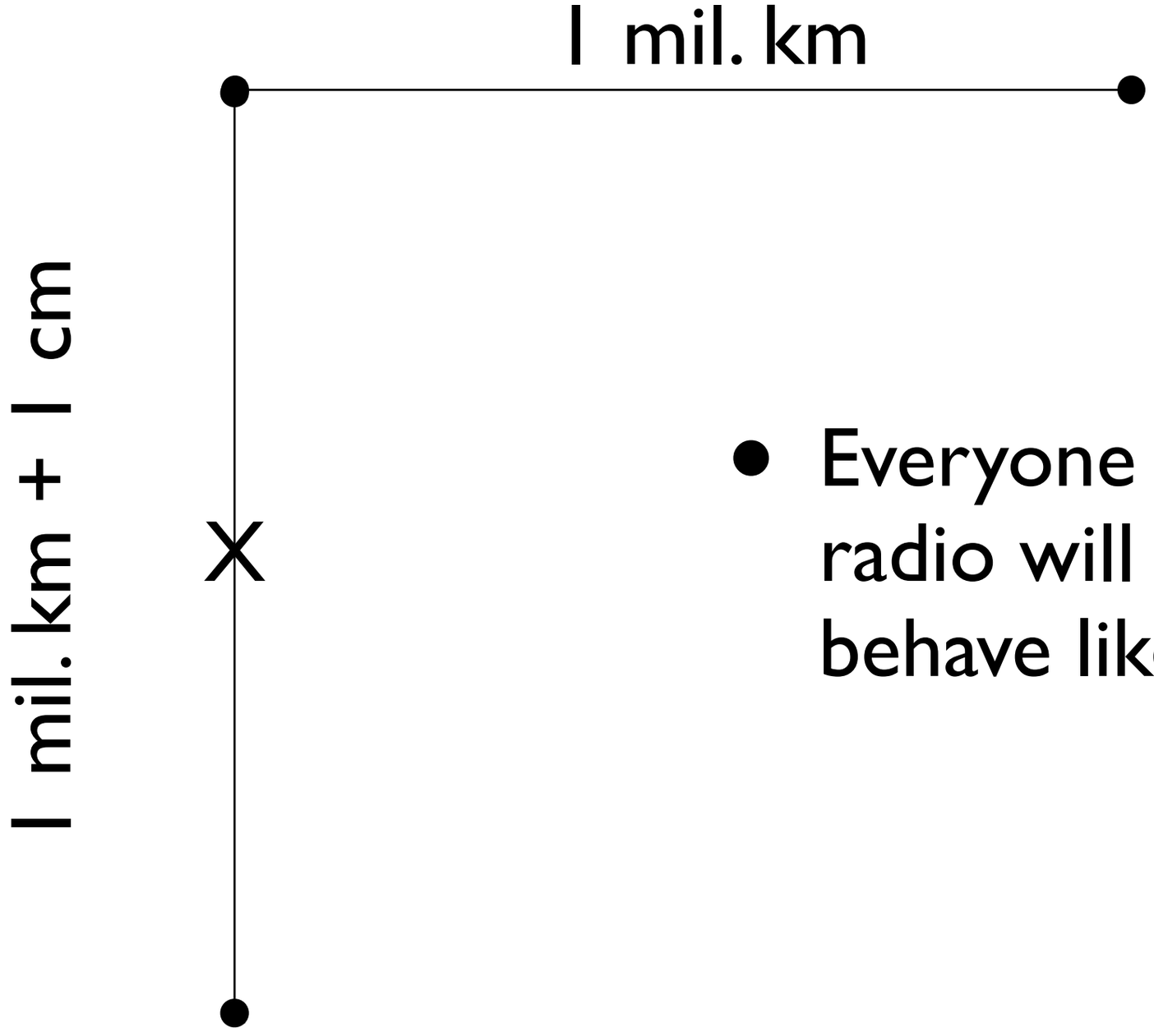






- Actually it is not math but still networking and energy

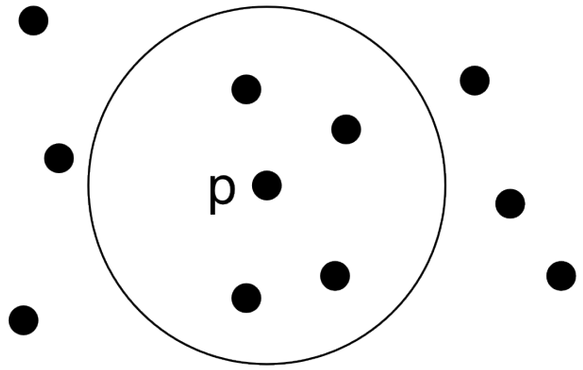
Geometrically Everything is Nice

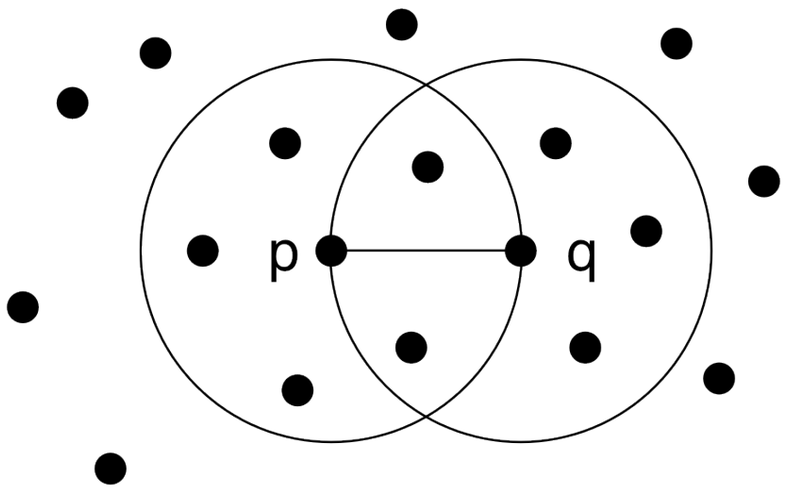


- Everyone knows radio will not behave like this

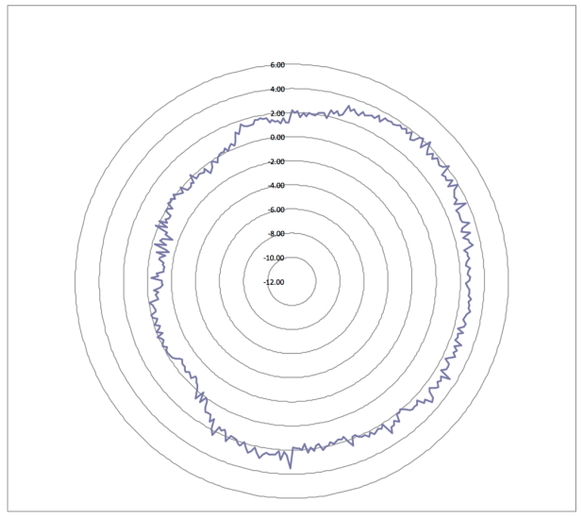
I Forgot One Thing

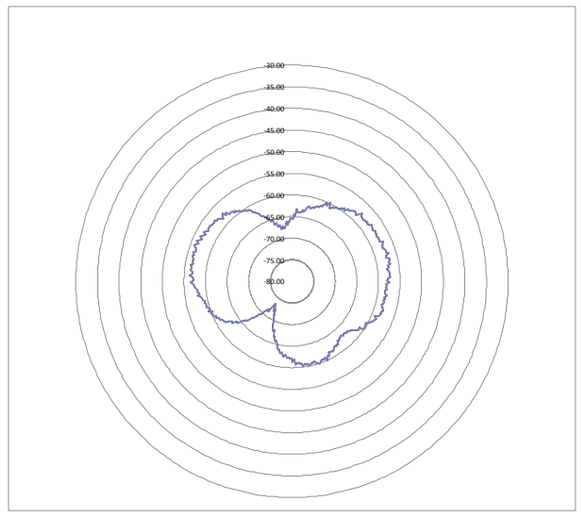
- Geometry





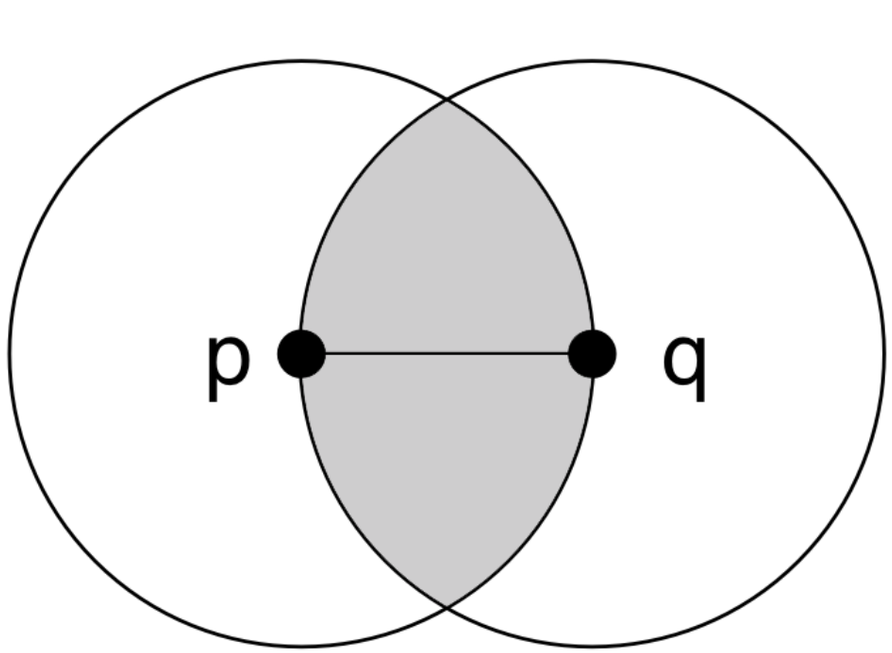
- Reality

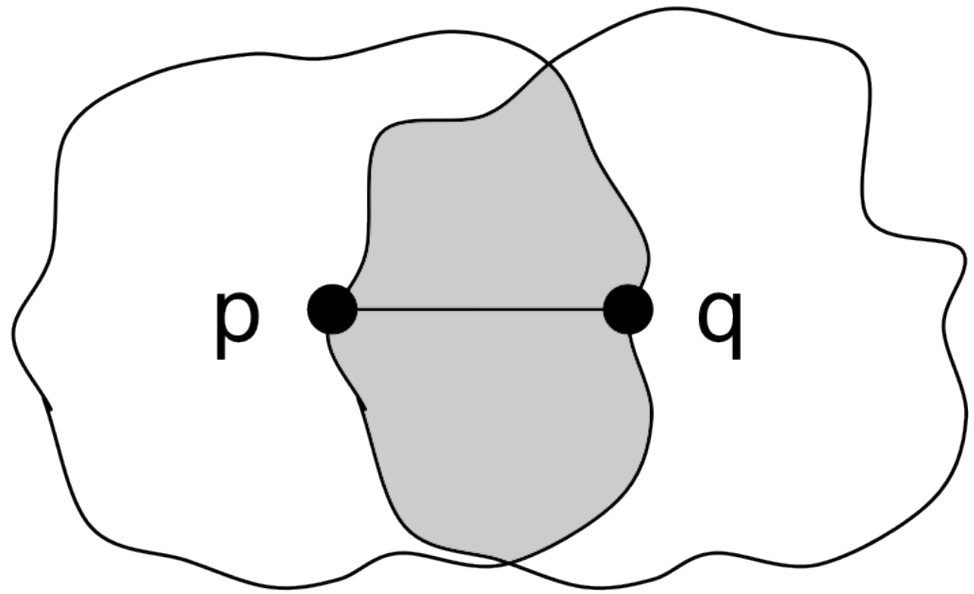




So We Adapted

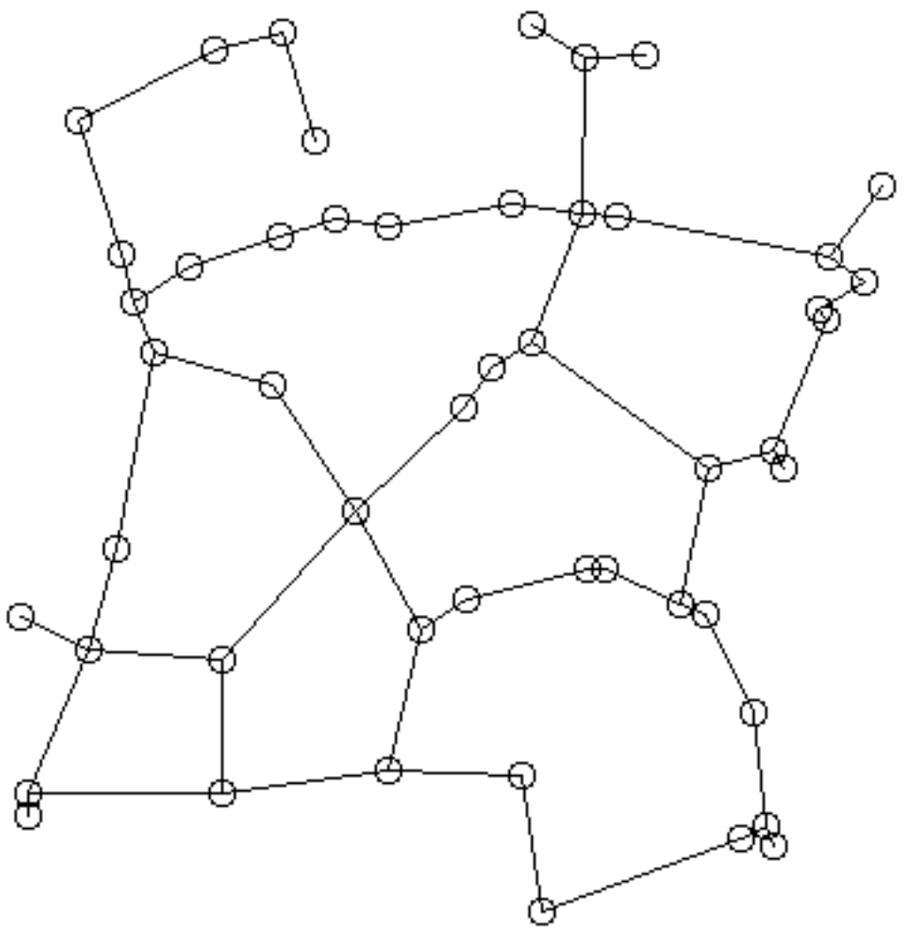
- RNG for Example



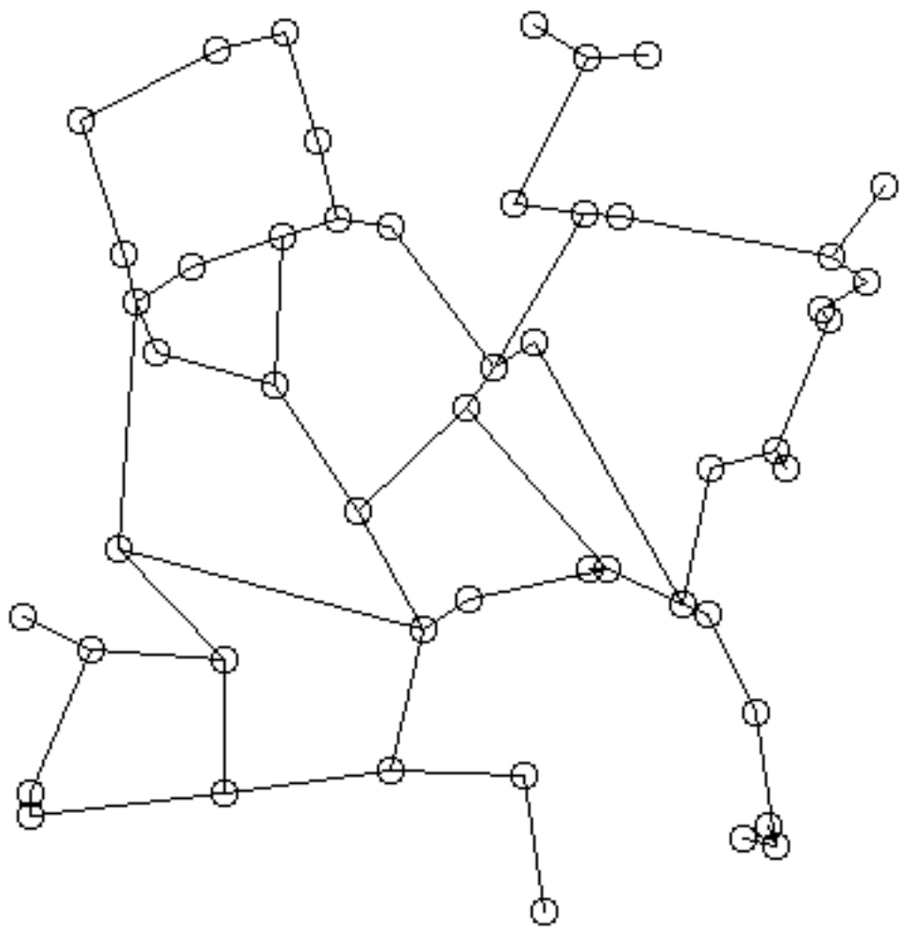


The Network

- RNG



- ARNG

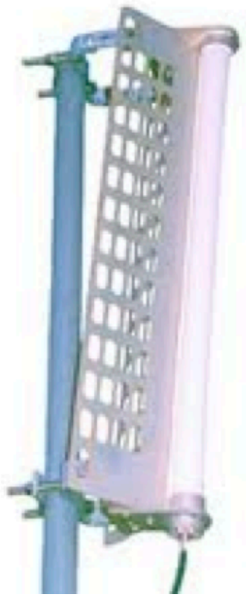


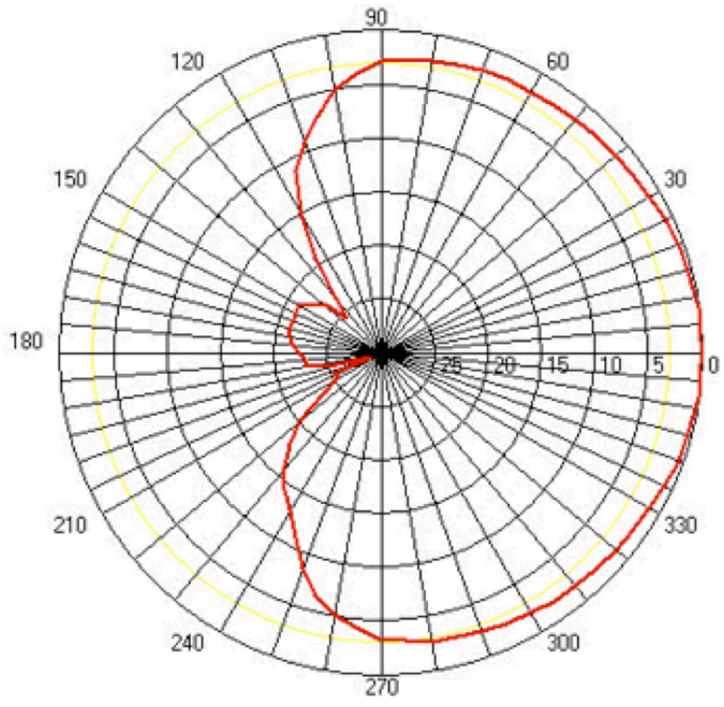
Conclusion 1

- It does not stop at an invisible barrier
- If everything is taken into account, results are far worse than geometry tells us

Can We Use Antennas?

- To decrease interference?
- Yes





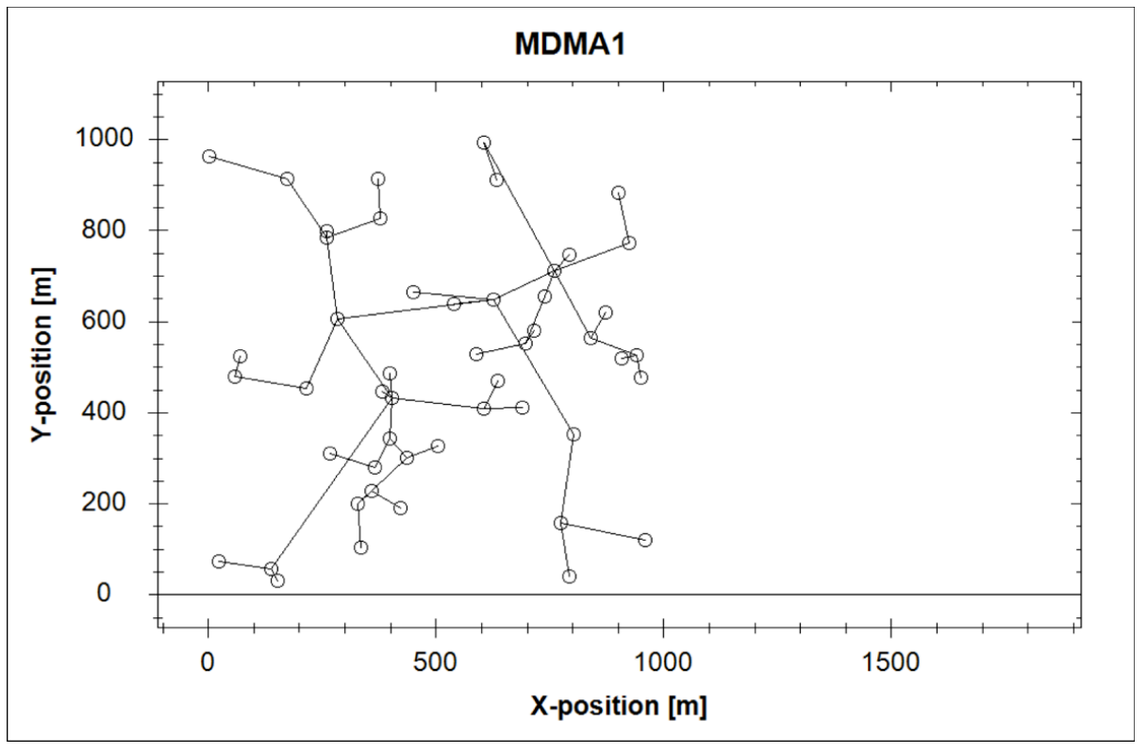
So Let Us Use Them

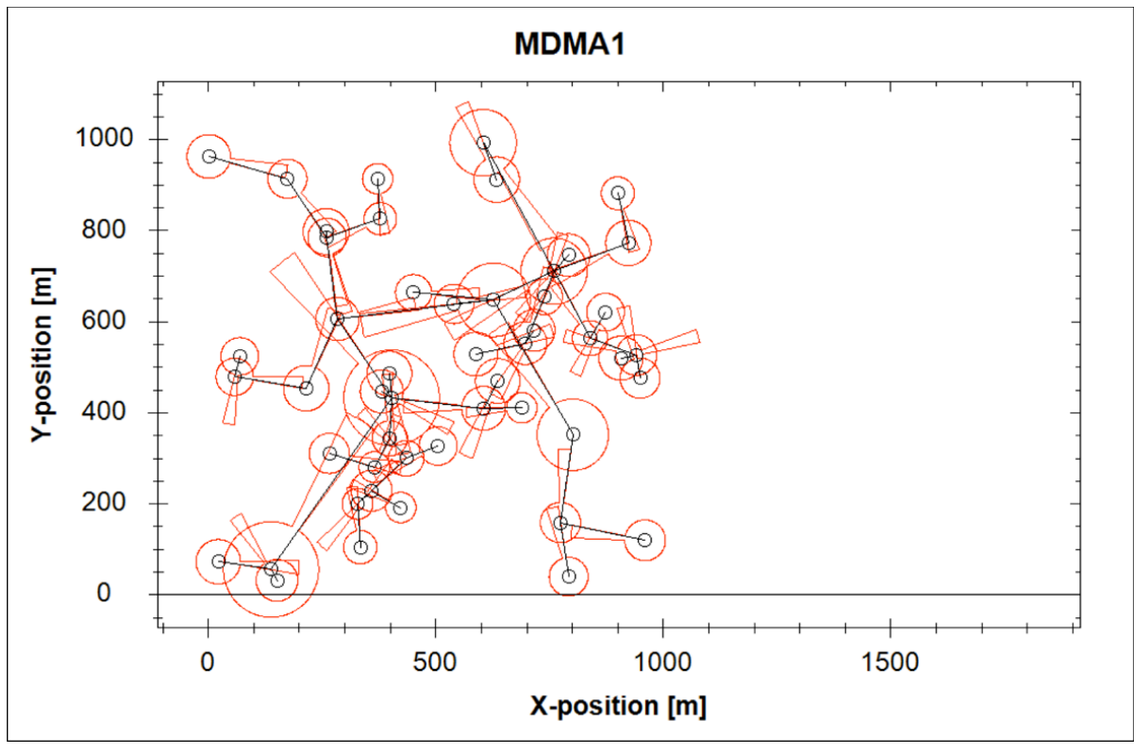
- And turn the antennas towards the closest neighbor

- Ups, disconnected network!

A Little Bit Smarter

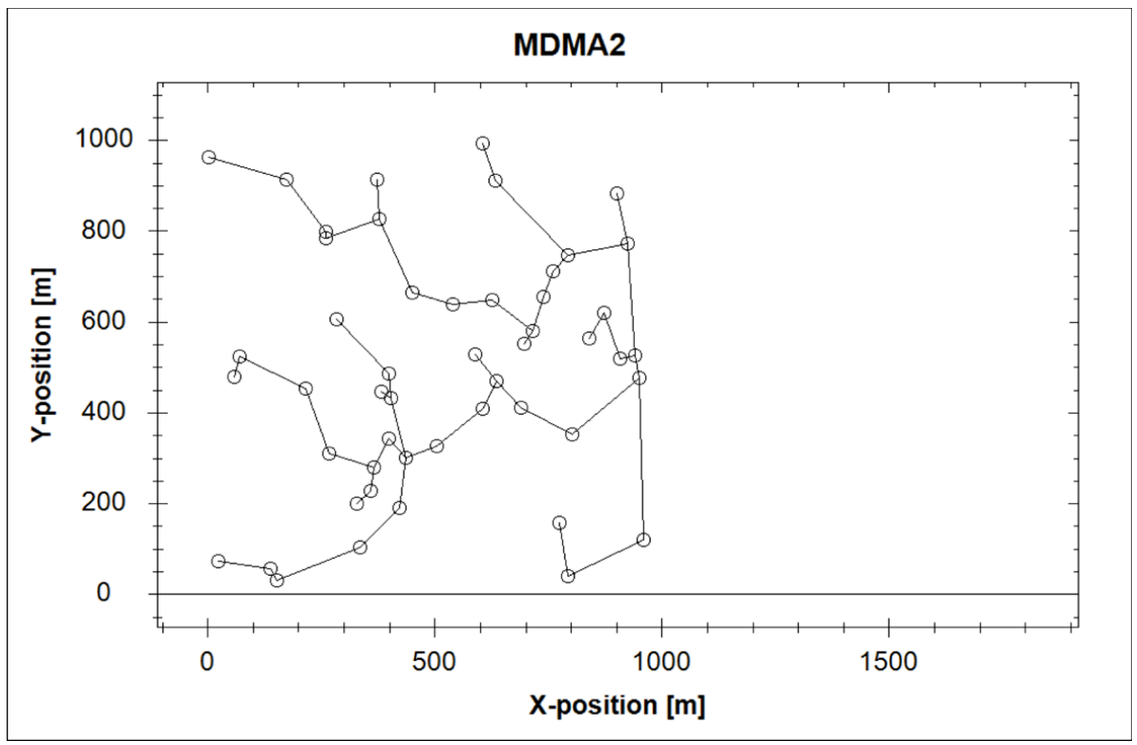
- Address the modules uniquely
- Connect to the closest with the address higher

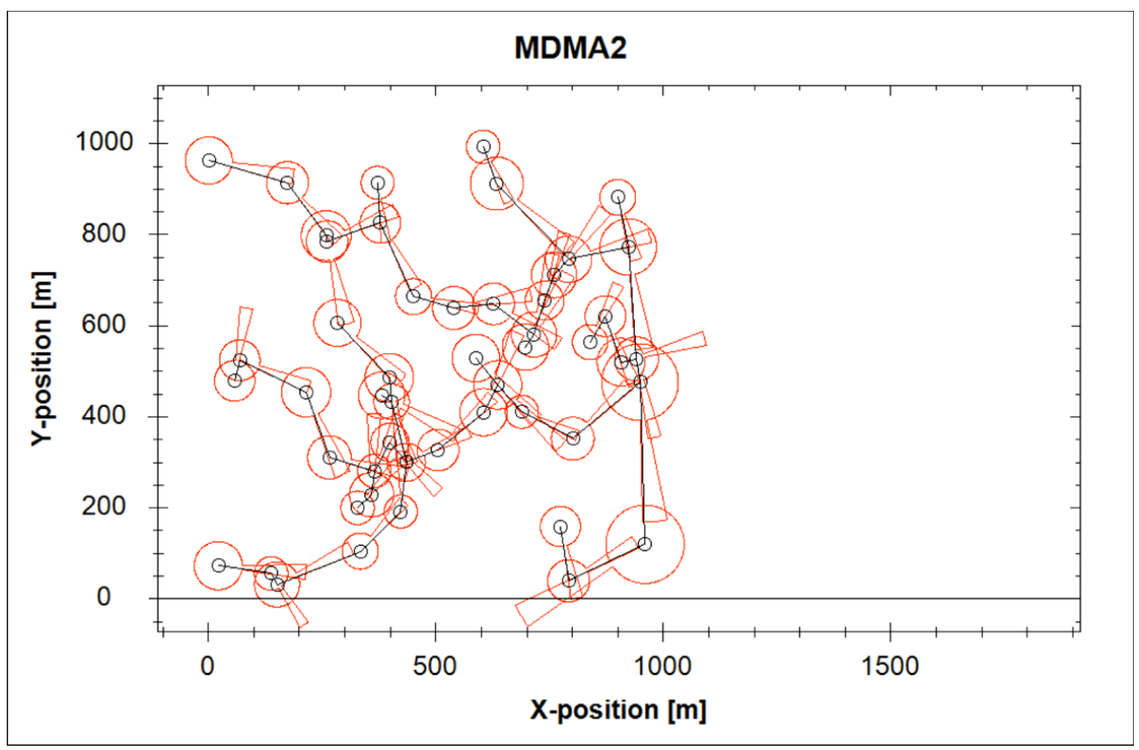




A Little Bit Even Smarter

- Address the modules uniquely
- Connect to the closest with the address higher
- Allocate the addresses by position



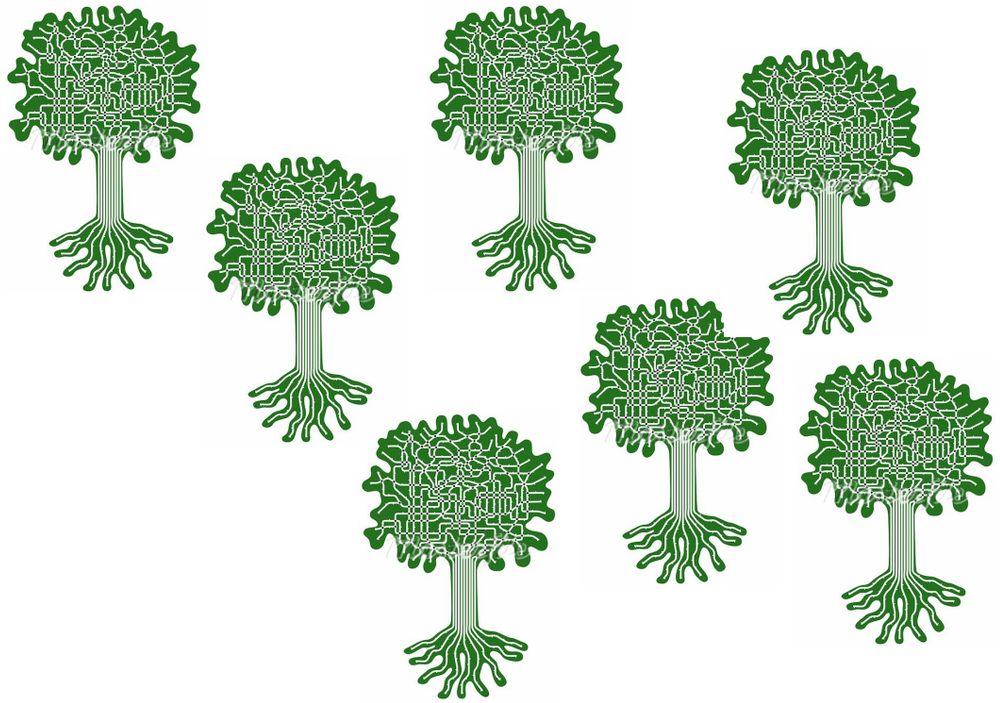


Conclusion 2

- For precise antennas the interference gets close to the geometrical methods, even when we use the constraints of reality

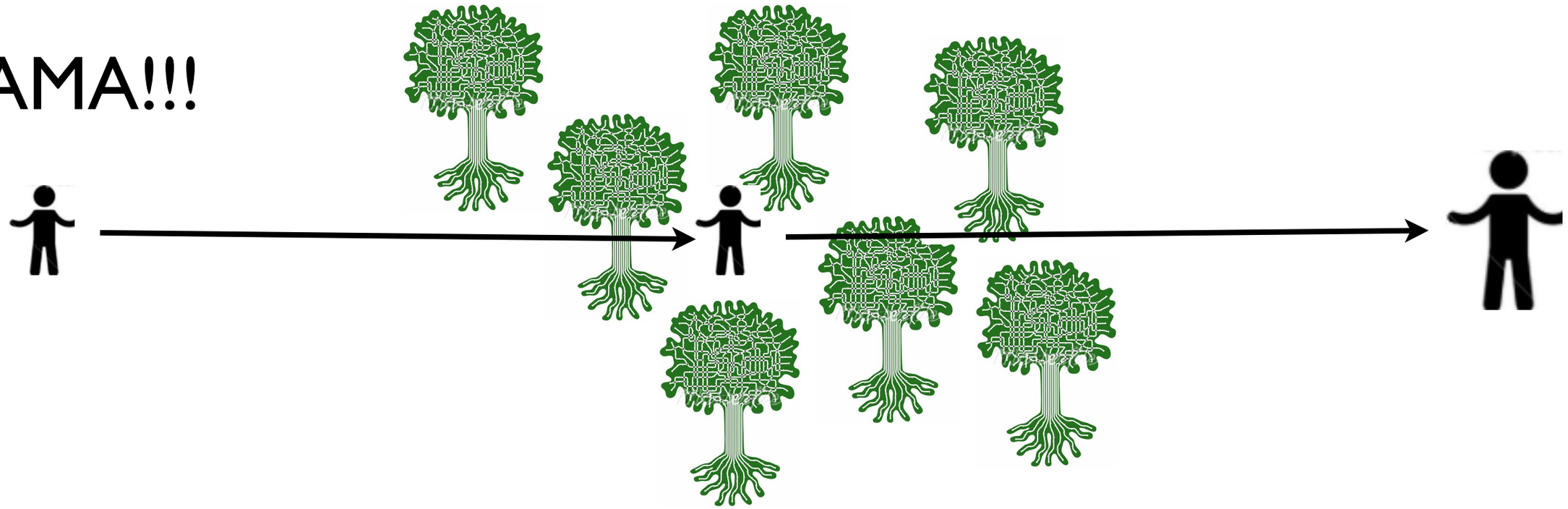
Collaboration

MAMA!!!



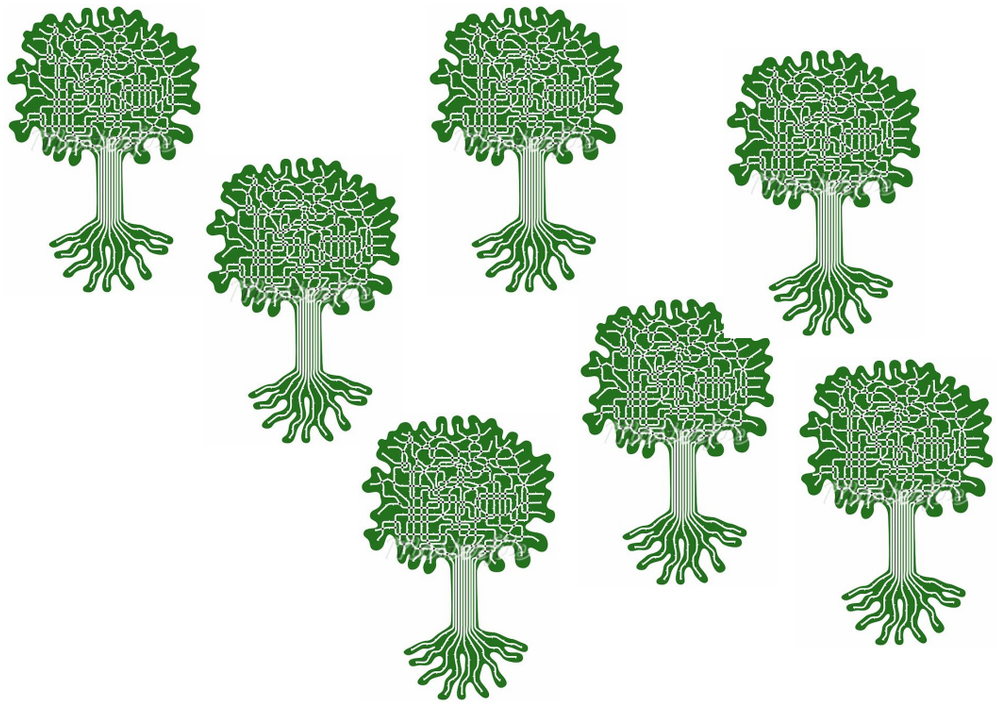
Collaboration

MAMA!!!



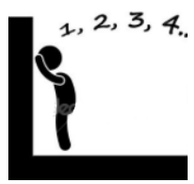
Collaboration
Missing Something?

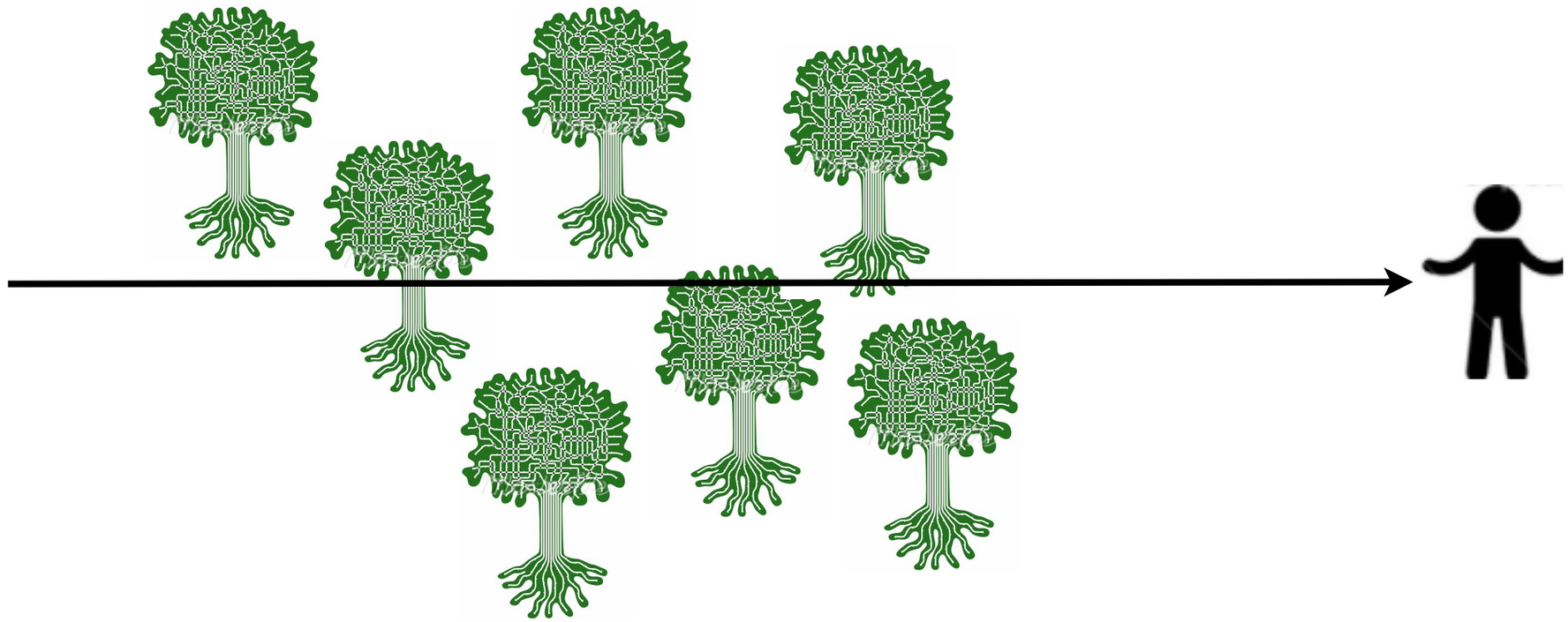
MAMA!!!



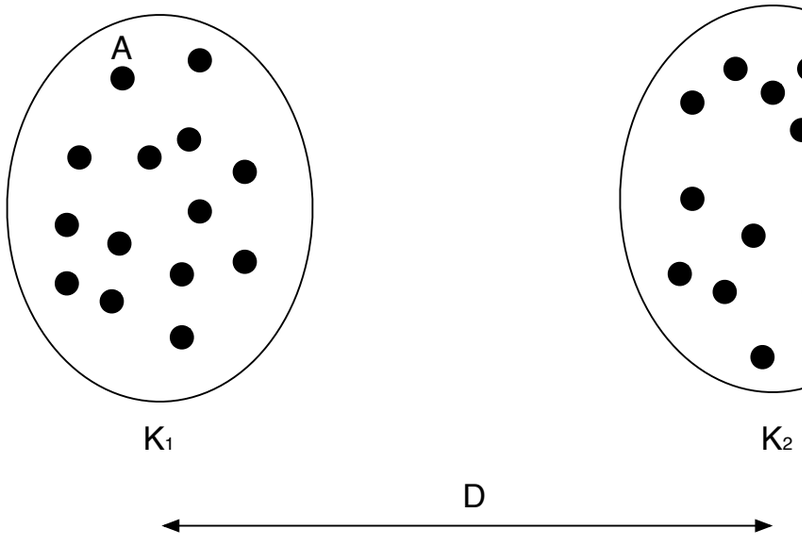
Collaboration

MAMA!!!

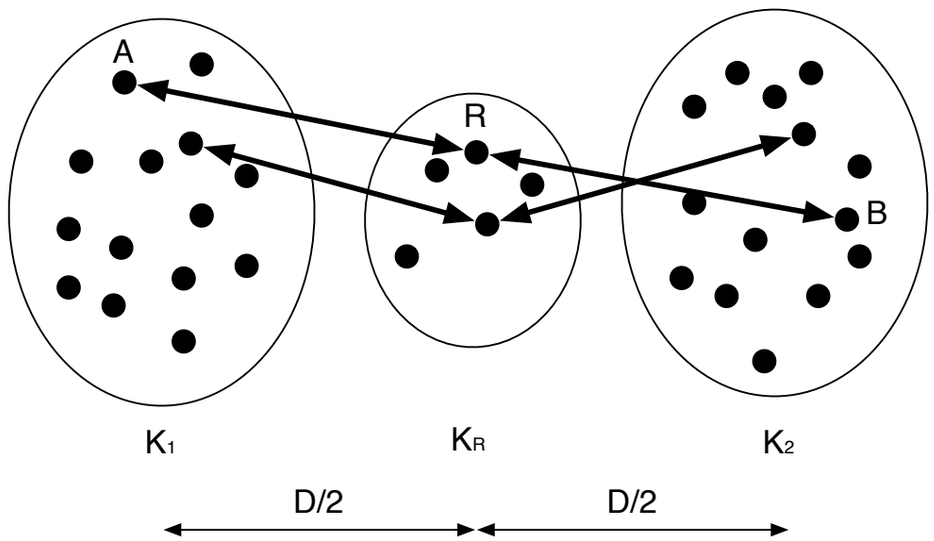




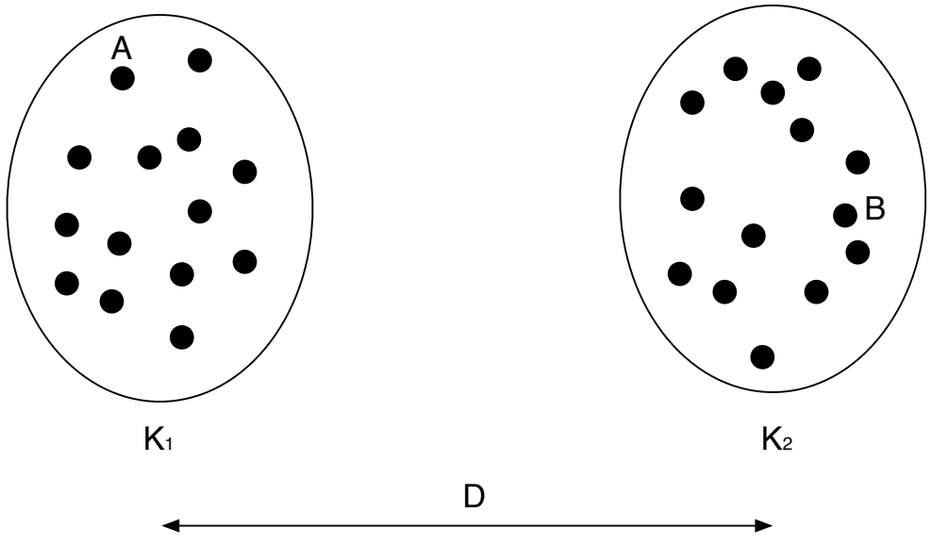
In Networks



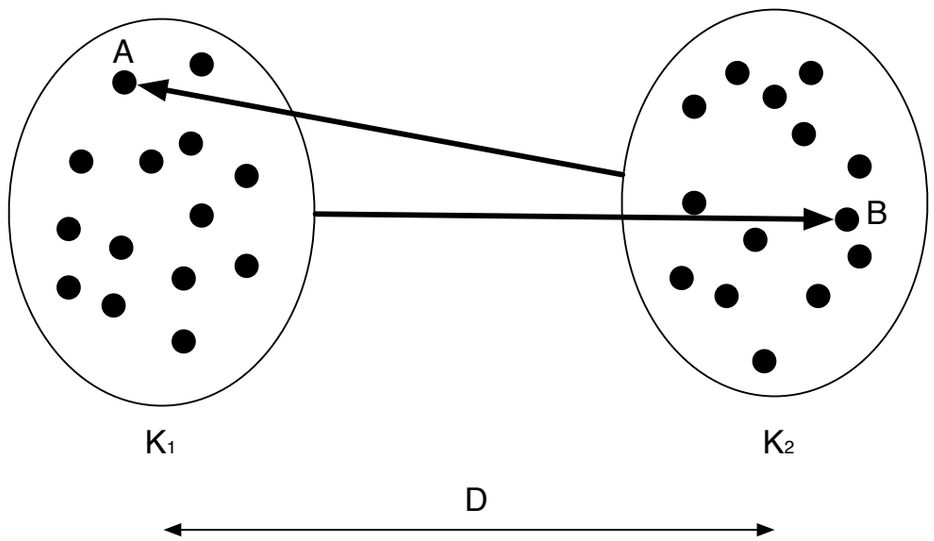
Relaying



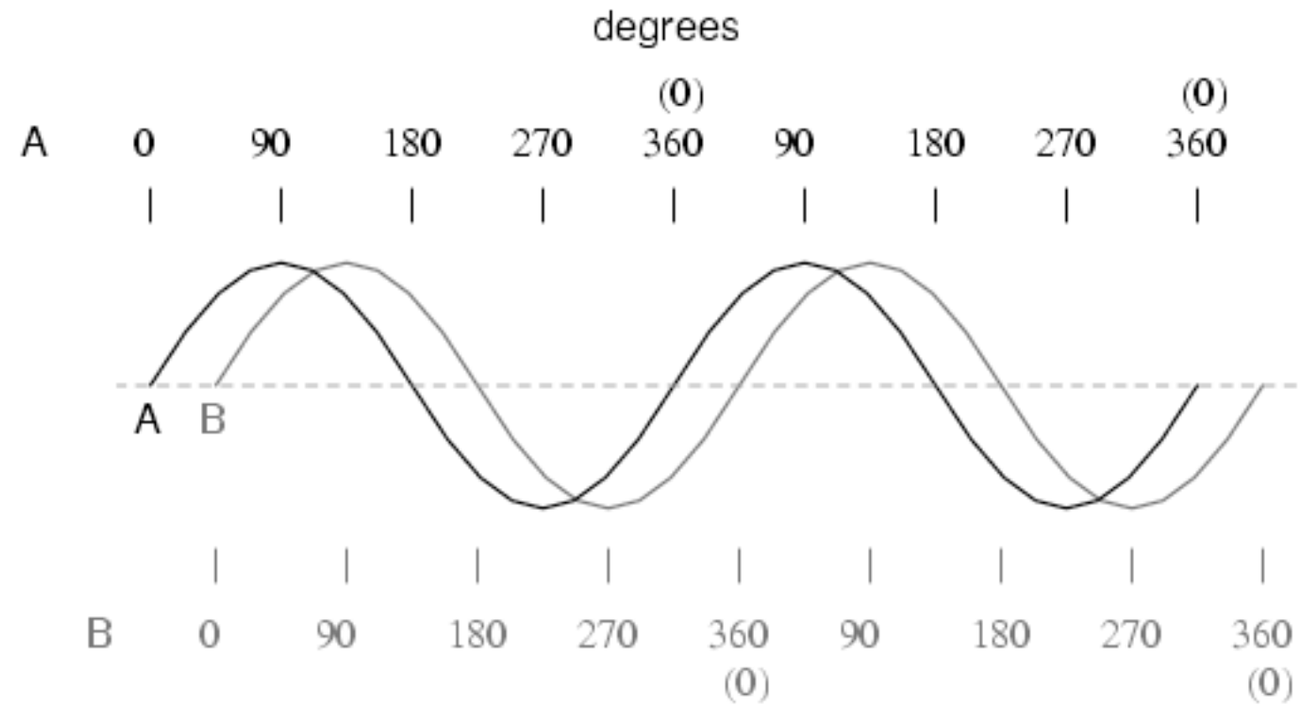
In Networks

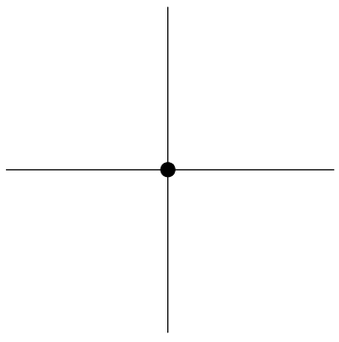


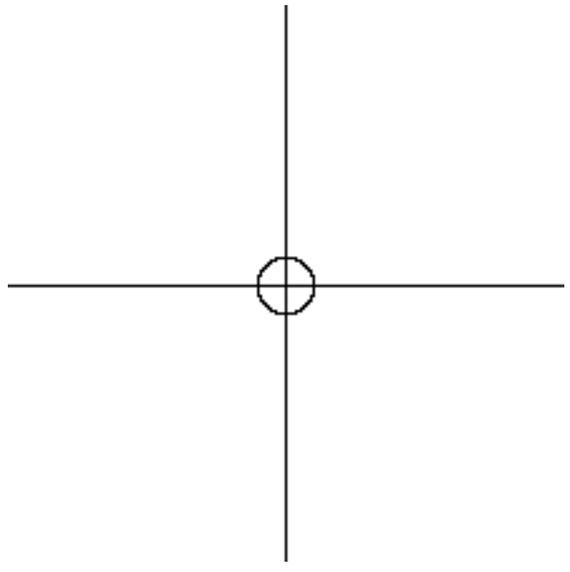
Beamforming



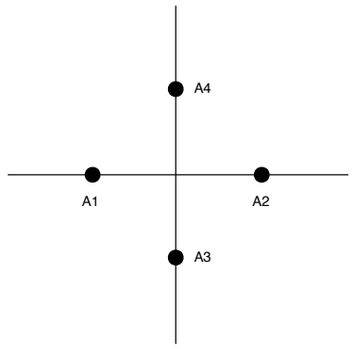
How Is This Possible?

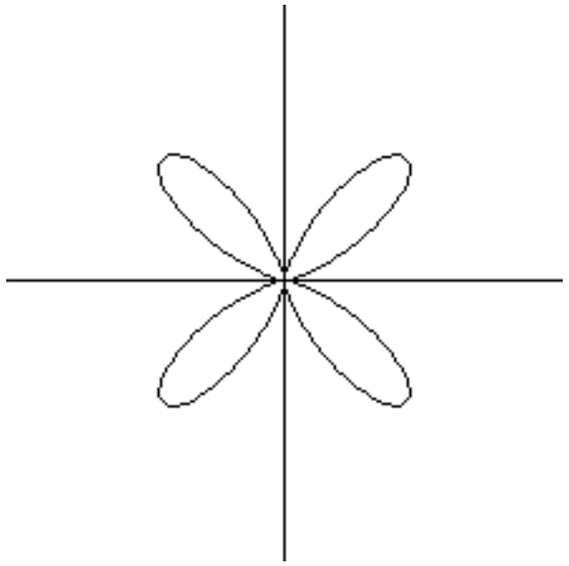


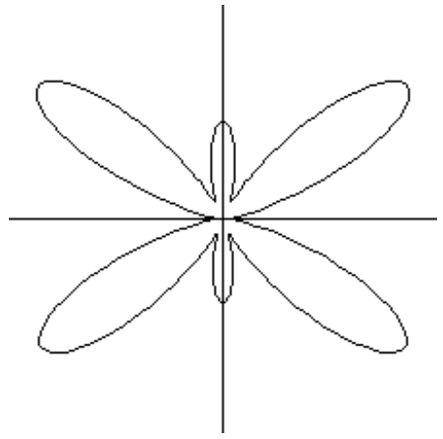


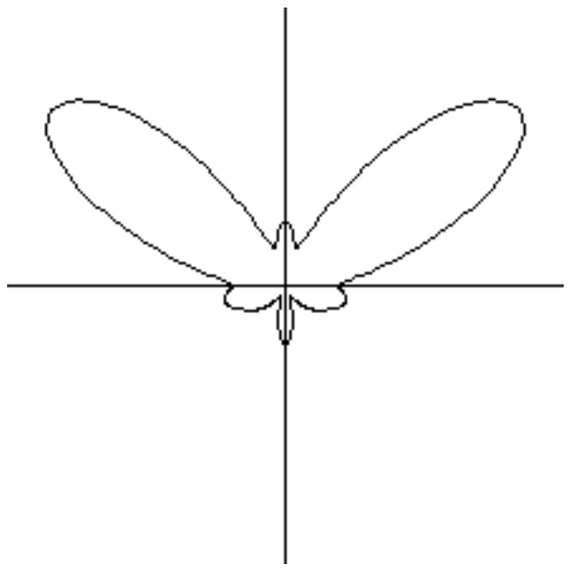


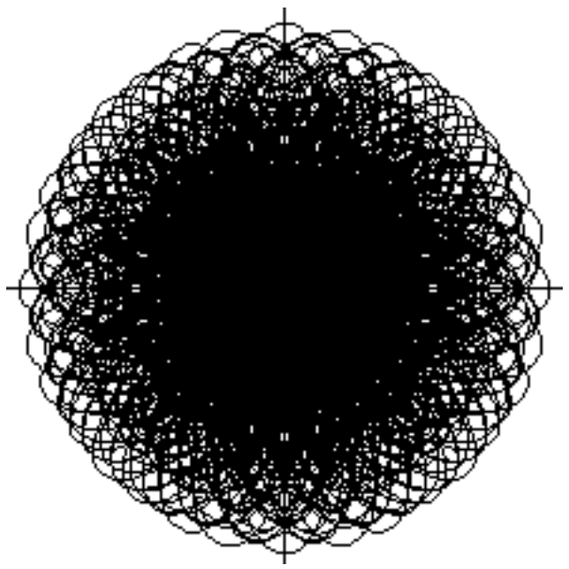
Combination of Signals











To Achieve That

- One module has some information
- It shares it with its neighbors
- They synchronize their signals
- Each delays a little bit the signal
- They transmit together

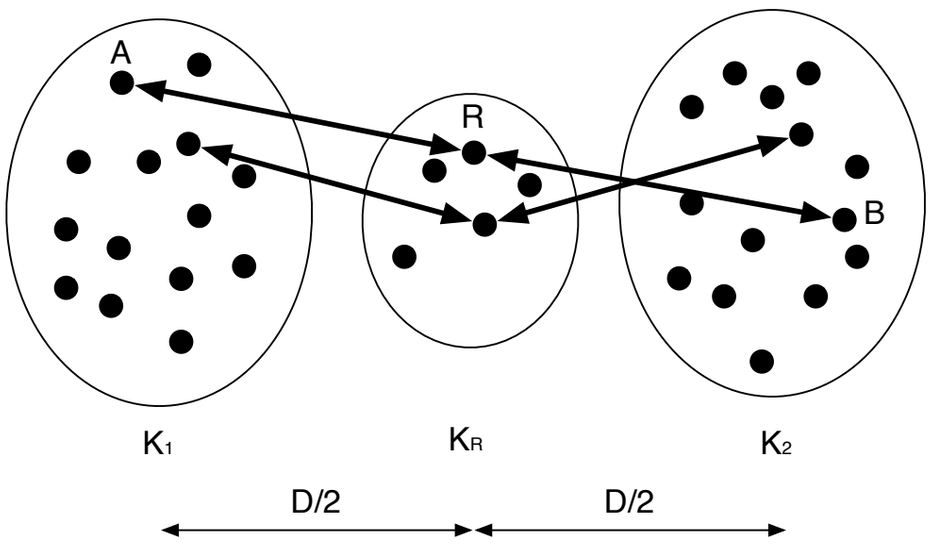
The Problems

- How to keep the signals in sync?
  - Answer: special hardware that we designed and submitted for patenting.
    - Actually it came back due to the fact that two other designs were similar. One from Bell Labs and the other from Nokia. Ours is better.
    - The others require that modules positions are a-priori known, with precision higher than the wavelength (less than 12 cm!). We do not need that.
- How to find the required small delays in signals?
  - Answer: hardware + algorithm which finds them

Conclusions 3: The Pros

- The method does not depend on hardware delays, constant delays, scatter, obstacles or almost anything;
- The method is optimal (at the limits of hardware);
- Sometimes better than relaying.

When Is It Better?



Conclusions 3: The Cons

- No movement allowed. If anything is moving, everything must be taken from the beginning;
- Long phase search (all possible combinations). It maybe improved. Even now for 4 modules it takes around 3 seconds to connect @ 115200 bps :)

The Future

- Faster phase search;
- Collision management;
- Routing;
- Combining the things here presented;
- Implementation;
- maybe others

10x

- 4 your attention
- And thank you to my team of NetworKings (Cerny, Fesl, Janecek, Kubr, Macejko, Votava)
(*alphabetical order)
- http://www.moucha.org/phd