Gathering in static radio networks

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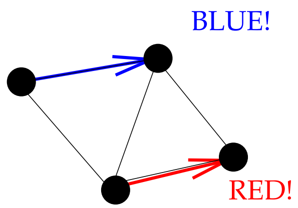
Contents

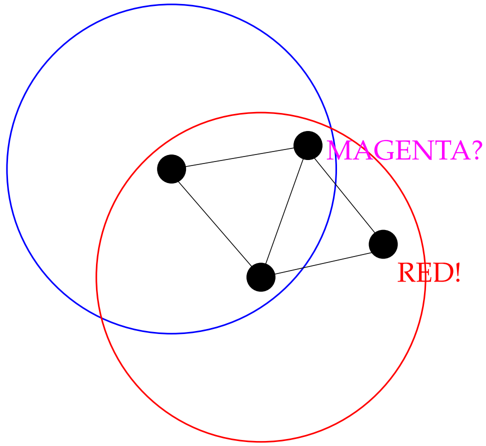
- Radio networks…
- …and they associated problems.
- Our problem: *Internet dans les villages*.
- A short introduction to approximation theory.
- Results and further research.

RADIO NETWORKS

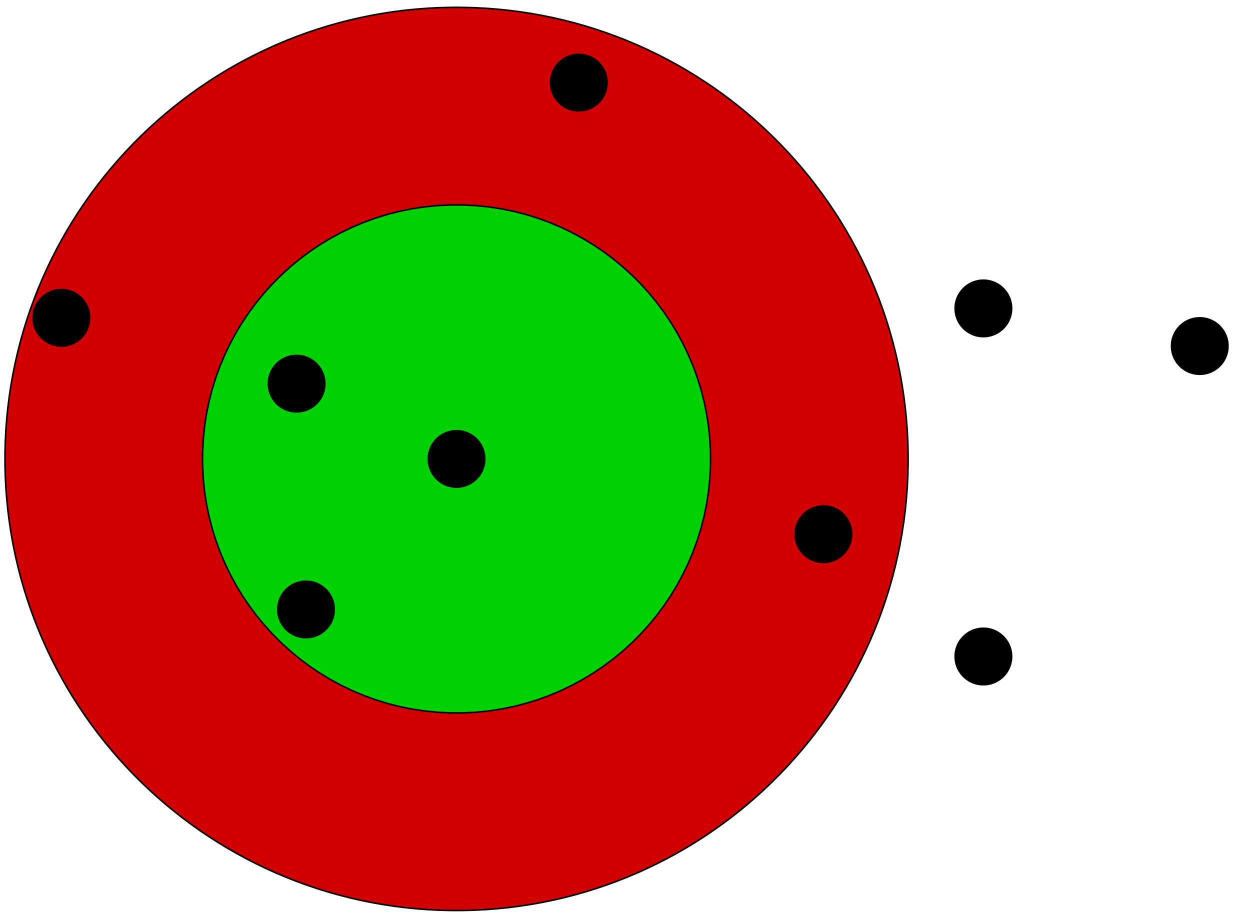
In classical networks, the capacity of an arc does not depend on the charge (use) of the others.

In radio networks, a transmission through (use of) an arc *blocks* others from being used.

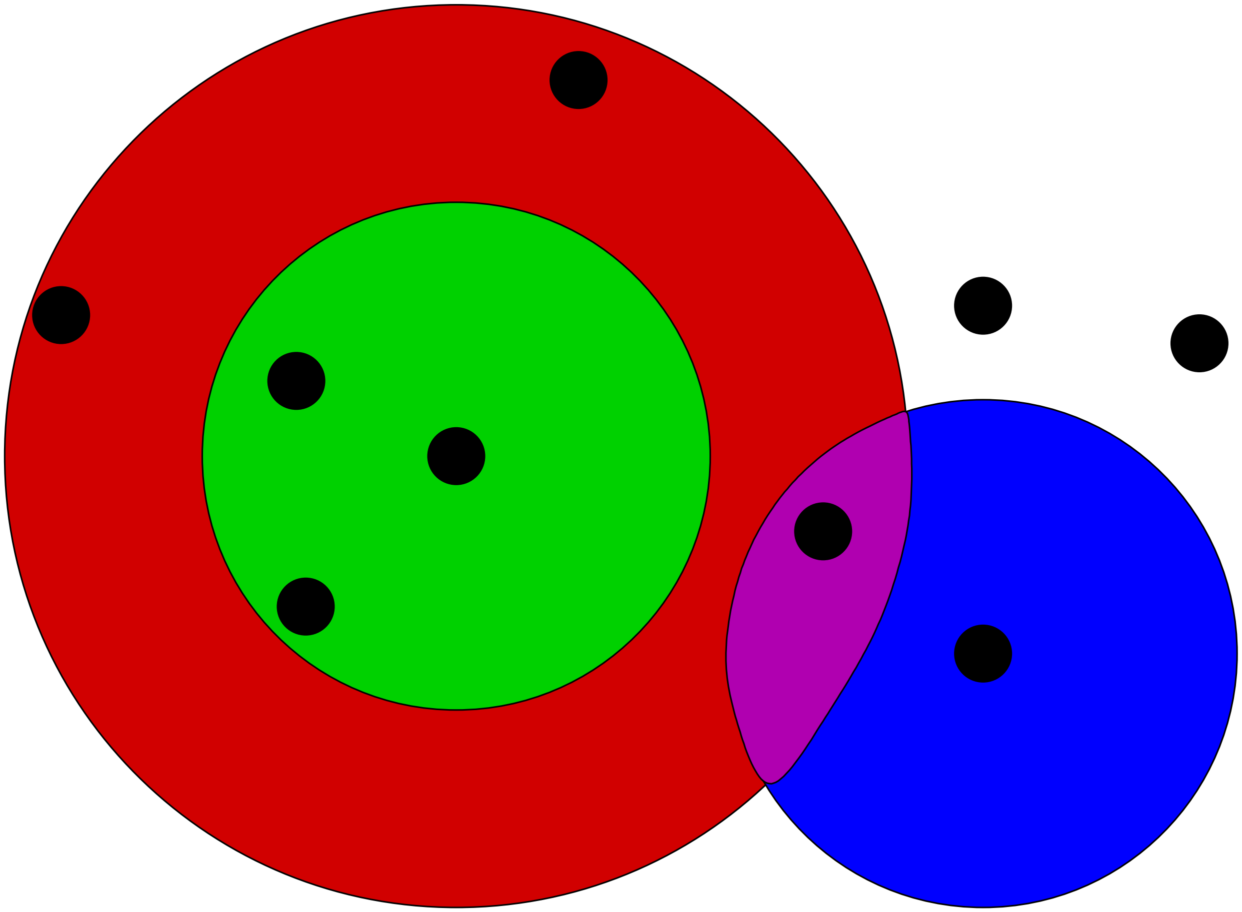




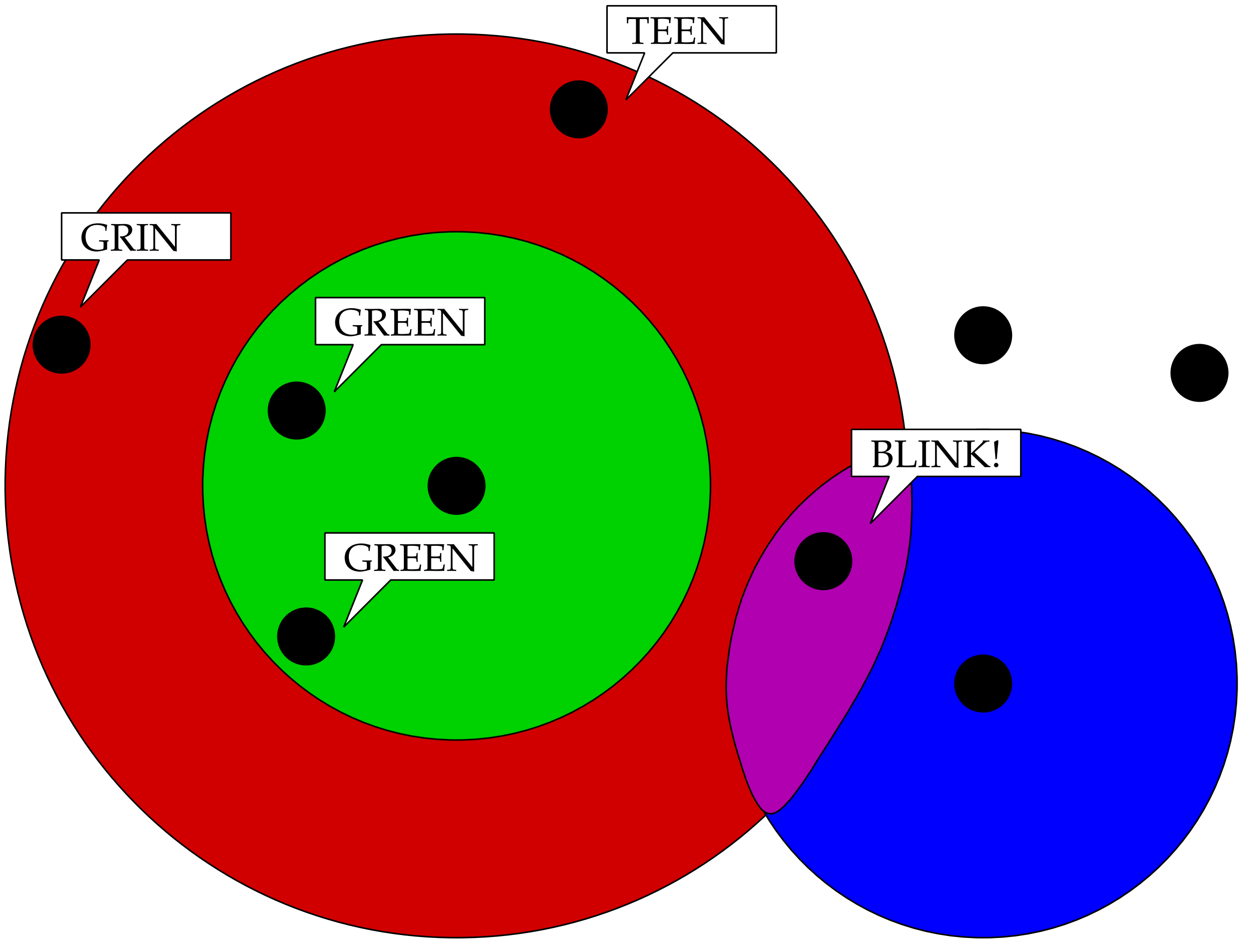
RADIO NETWORKS



Radio networks



Radio networks



THE PROBLEMS

- Due to the interference constraints, the devices in a radio network must act cooperatively in order to achieve effective flow of information in the network.
  - Broadcasting: A specific node has a piece of information to communicate to all the others.
  - Gathering (and Personalized Broadcasting): There is one central node that has to accumulate information from everyone.
  - Gossiping: A message from anybody to everybody.
- Design: Where to put the devices.
- Energy: How to reduce the number of transmissions to save battery life. (Ex. *Sensor networks*.)
- Security?

Classic Model

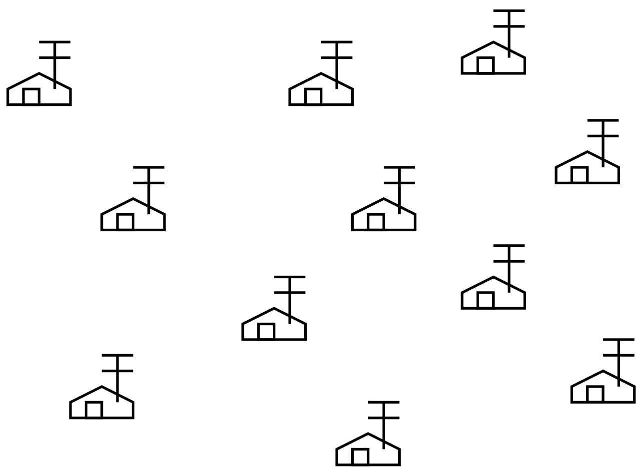
- In the classic model it is assumed that the transmission and interference distances are the same (and equal to 1).
- A lot of results, but mainly
  - For broadcasting (Flood! Flood! Flood!).
  - Heuristics validated through simulations.

OUR PROBLEM: *How to bring Internet to villages…*

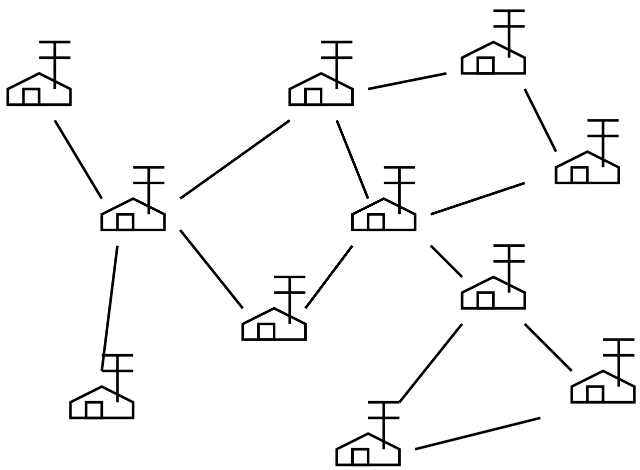
- …without using wires.
- Idea: Put a central antenna and provide the houses with wireless devices. The antenna acts as a gateway (like mobile phones, but *multihop*: no direct connection between every device and the central antenna).
- Gathering+Personalized Broadcasting!

INTERNET DANS LES VILLAGES

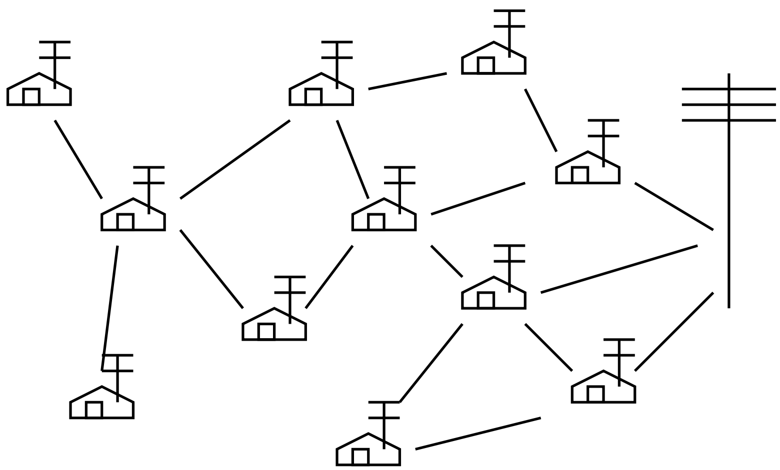
Internet dans les villages



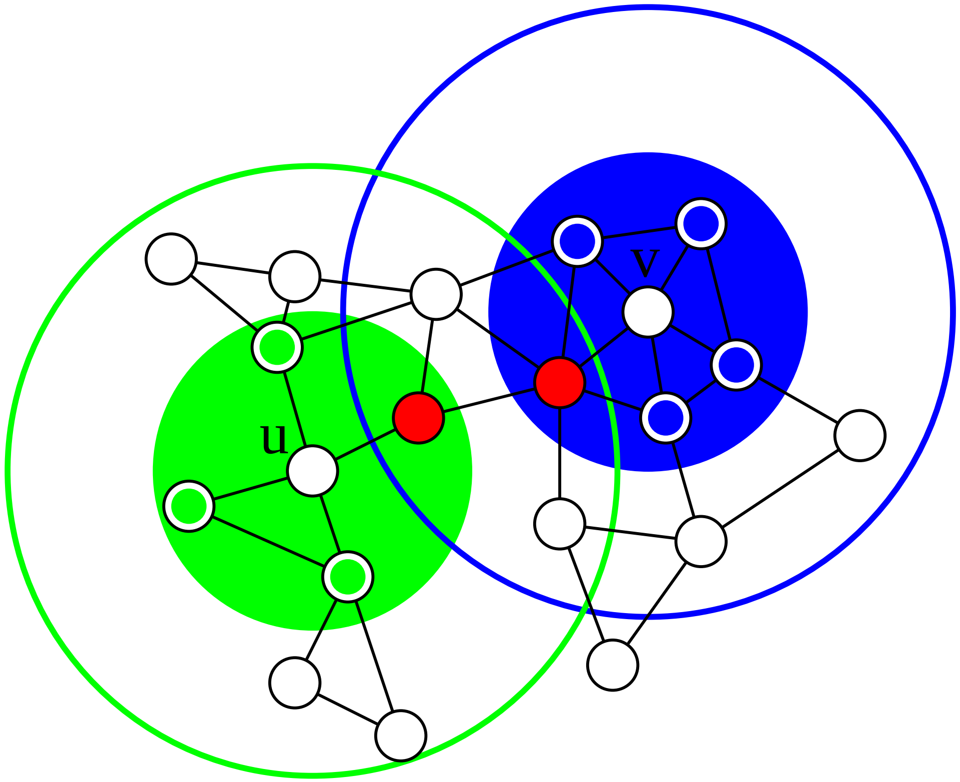
INTERNET DANS LES VILLAGES



INTERNET DANS LES VILLAGES



The model



THEORETICAL BACKGROUND

- (Very) well known fact: Interesting/useful problems are NP-HARD. (Ours is hard, so it may be interesting!)
- Approximation: Do not look for a solution, but something *good*. For a minimization problem, we look at the *approximation ratio*

$$r_A(x) = \frac{value(A(x))}{opt(x)}.$$

- An approximation scheme: $B(x, \epsilon)$ is such that $r_{B(\cdot,\epsilon)}(x) \leq 1 + \epsilon$.
- A FPTAS. The time it takes to calculate the approximation is polynomial on $|x|$ and also on $|1/\epsilon|$.

OUR RESULTS

- In general the problem is not only NP-HARD, but it does not admit a FPTAS.
- A 4-approximation: $r_P(x) \leq 4$.
- *Nearly optimal* solutions for some specific topologies.
- In:
  - Complexity of bandwidth allocation in radio networks: the static case (submitted to TCS+INRIA Research Report).
  - Hardness and approximation of Gathering in static radio networks (submitted to FAWN+IRR).
  - Nearly optimal protocols for gathering in specific radio networks (manuscript).

Further directions

- Complexity for specific topologies.
- Design: Where to put the central antenna?
- What if there are several antennas?
- What to do only with local knowledge?
- Fault tolerance?
- …

Thank you

Merci

Gracias

PAPER 1 — STEADY STATE DEMANDS

- Network $G = (V, E)$ and demand function $f(u, v) : V \times V \to \mathbb{R}^+$.
- A pattern is a set of transmissions that are compatible.
- **How often** have patterns to be applied in order to satisfy the traffic demands?
  - Hard even if $f(u, v) = 1$ iff $v = v_0$ (gathering).
  - Polynomial in the path and trees.
  - PTAS when the vertices are in $\mathbb{R}^k$.

PAPER 2 — GATHERING PROTOCOLS

- Network $G = (V, E)$ with distinguished node $t \in V$. A function $m(u) : V \to \mathbb{N}$, representing the number of messages that u has to transmit to t.
- A protocol is a sequence of patterns.
- **When** do patterns to be applied in order to achieve gathering using a minimum number of rounds?
- General algorithm + General lower bound $\Rightarrow$ 4-approximation.

PAPER 3 — SPECIFIC TOPOLOGIES

- Gathering in the uniform case (or: *How many clients can we have?*)
- Specific (realistic) topologies: The 2D-Grid.
- Our protocols are *very good* in the next sense. If $\mathcal{G}(x)$ is the optimum gathering time and our protocol spends $P(x)$ with $x = (G, t)$ being a gathering instance, then

$$P(x) - \mathcal{G}(x) \leq C, \; C = C(d_T, d_I).$$

In particular $r_P(x) \to 1$ as $|x|$ grows.