Handling Interference Using Distributed Cooperation

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EURECOM
Sophia Antipolis

About EURECOM

A shared grad school and research center on communications systems in Sophia-Antipolis (F)

Academia

TELECOM ParisTech

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Aalto University School of Science and Technology

Technische Universität München

NTNU Norwegian University of Science and Technology

VIETNAM NATIONAL UNIVERSITY HO CHI MINH CITY

Industry

swisscom

SFR

orange

ST ERICSSON

BMW Group Forschung und Technik

CISCO

symantec.

Monaco telecom TELLEMENT MONACO

SAP

INSTITUT Mines-Télécom

Institut Mines Telecom is a founding member of EURECOM consortium

Speaking to a diverse audience

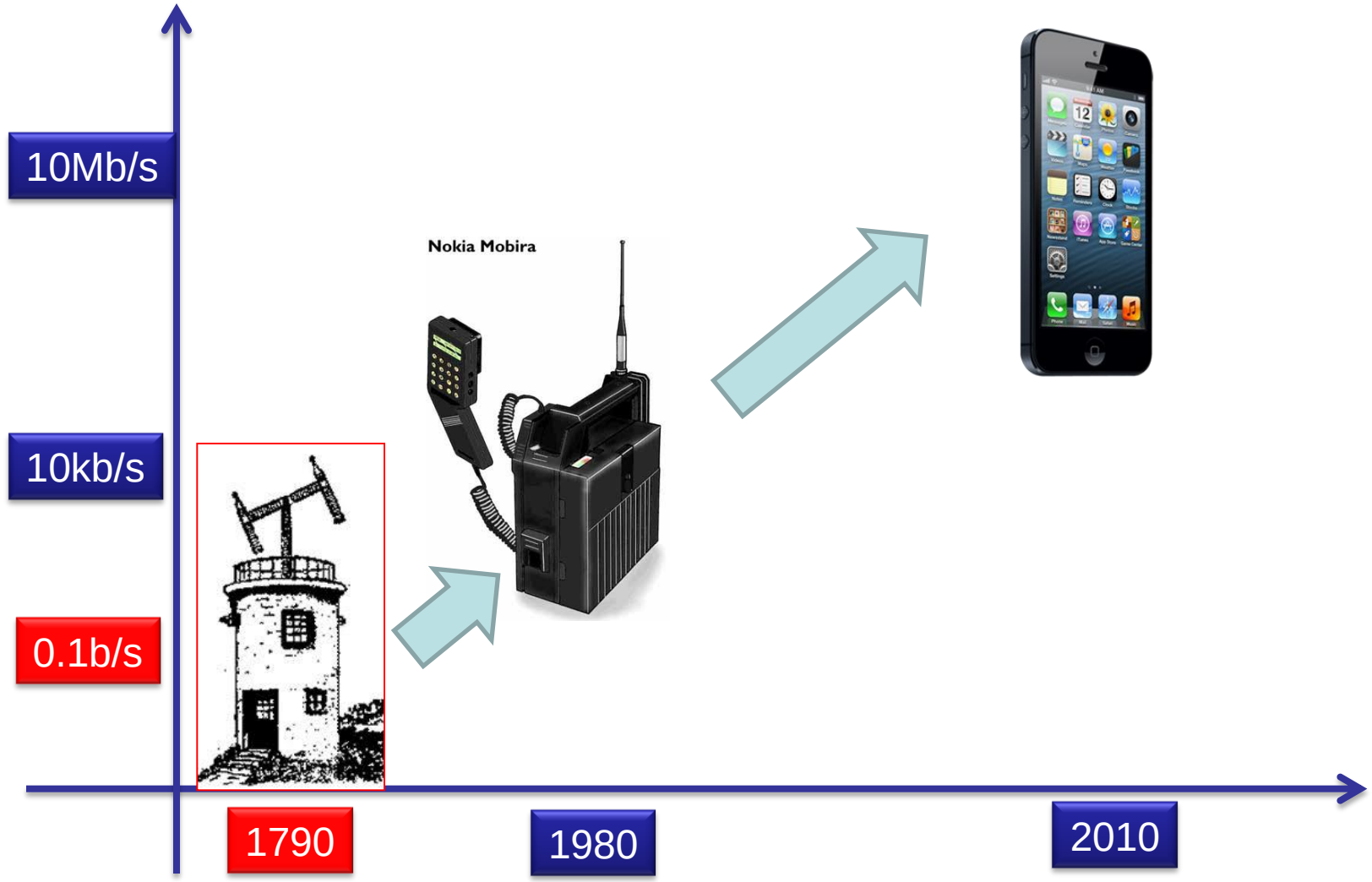
What does the trick (as per Google search):

1. Learn the demographics of the audience
2. Do not use humor that puts down any particular group
3. Do not try and share your religious beliefs
4. Be comfortable with silence
5. Reflect on nature of one's activity
6. Find common models
7. Identify opportunities for cross-disciplinary work

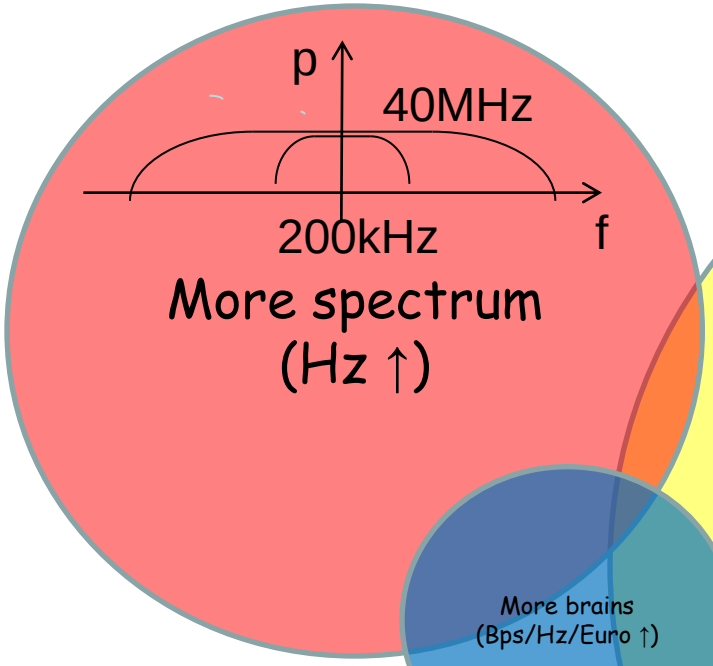
Heinrich Hertz (1857-1894)

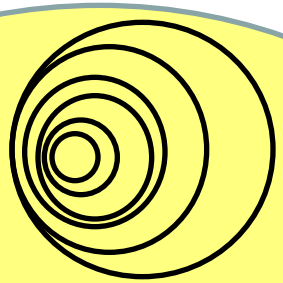
"I do not think that the wireless waves I have discovered will have any practical application." **(H.R.Hertz)**

From digital to digital…



Explaining wireless progress



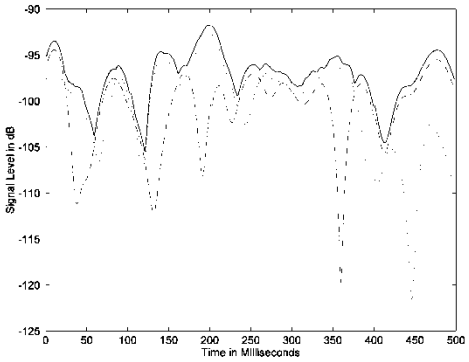


10km

200m

More hardware
(Euros/km2 ↑)

More brains
(Bps/Hz/Euro ↑)



Adaptivity
Coding
MIMO

The revenge of the brains

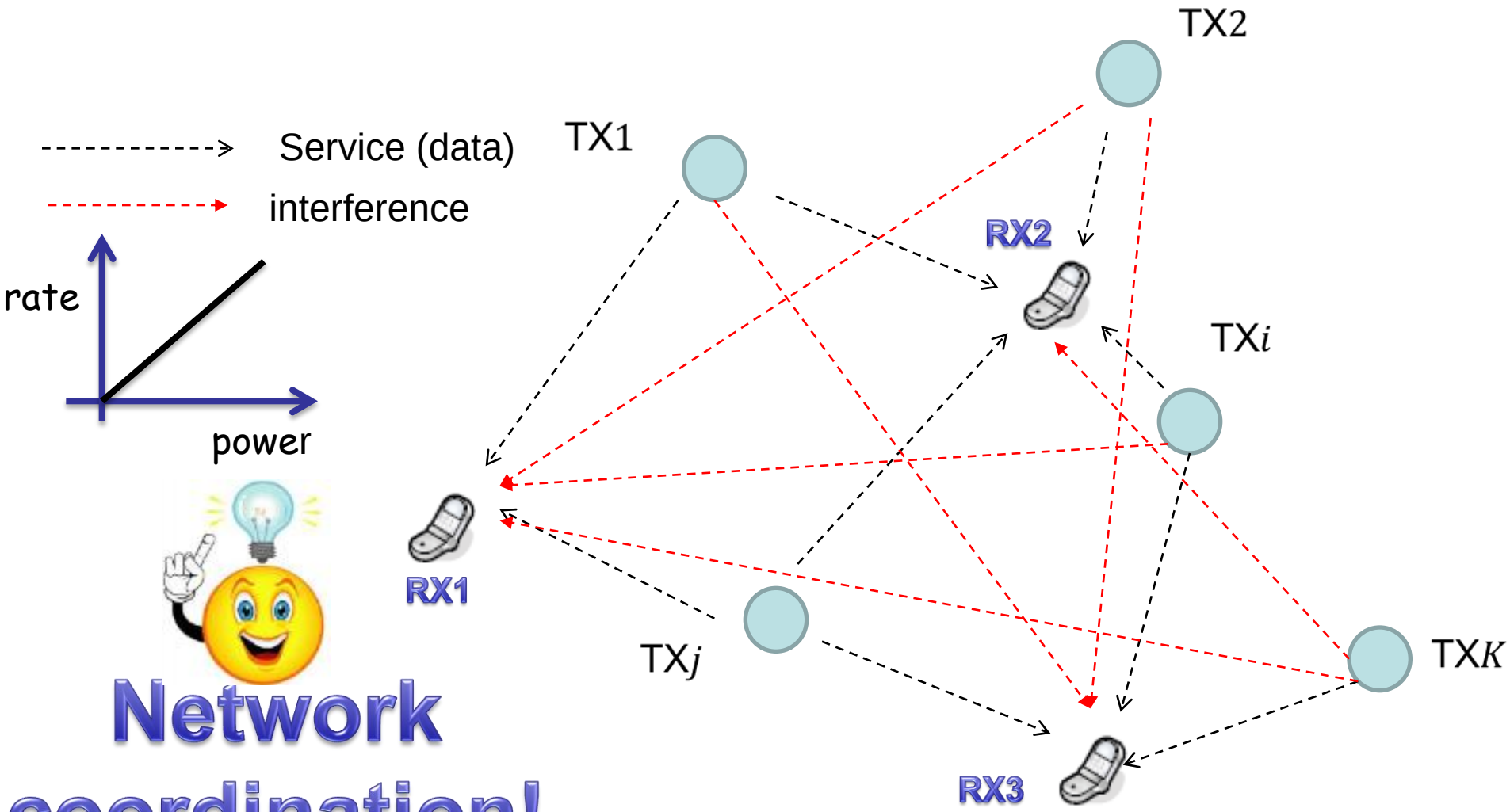
Five fundamental trends in wireless

1. Densification, miniaturization,
2. Machine dominated traffic (50B machines vs. 7B humans)
3. Cloud-radio
4. Aggressive frequency reuse
5. Self-organization

Interference!

Autonomy!

The service & interference graph



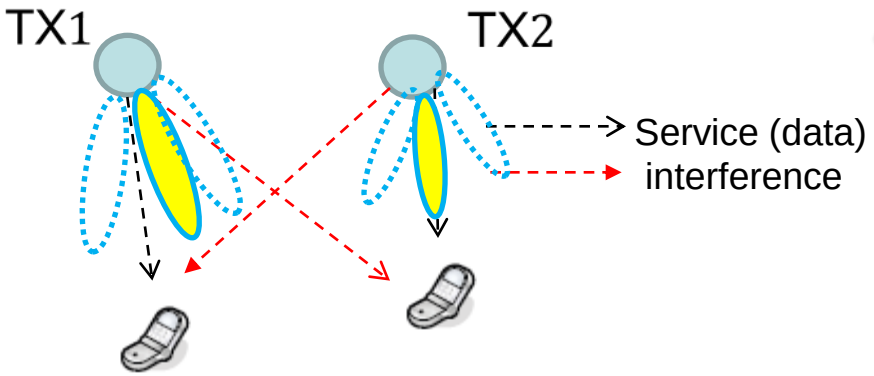
Modeling autonomous behavior with games

Key idea: Let autonomous transmitting devices interact to solve their interference conflicts

- **Players** -> transmitters
- **Actions** -> transmit decision (power, frequency, beam, ..)
- **Strategy** -> Utility maximization (max rate, min power, min delay,..)
- **Timing** -> simultaneous, sequential,..
- **Equilibrium** -> Nash, Stackelberg, Nash Bargaining,..

The price of selfishness

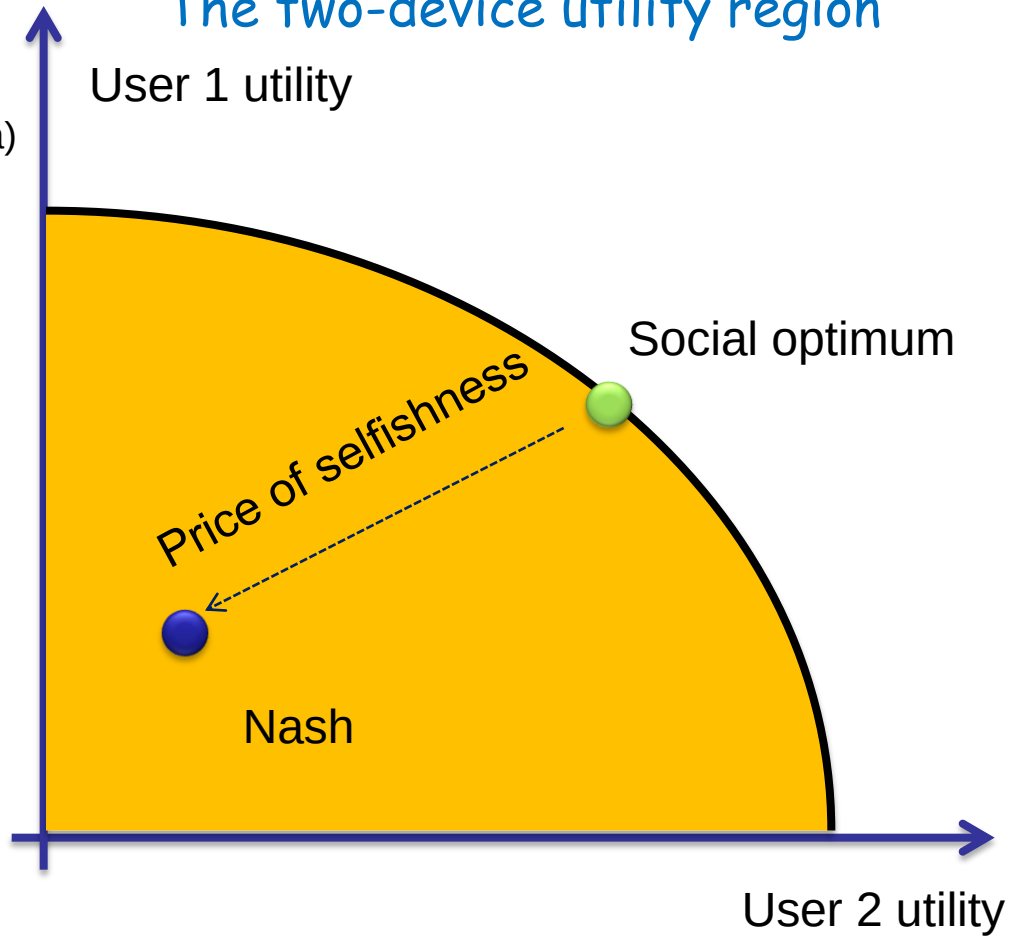
A two-device beamfoming game



Looming danger:
autonomy -> selfishness!

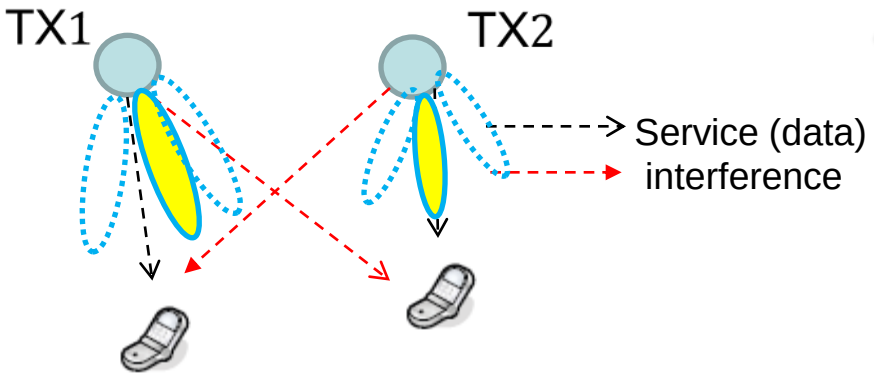
Nash (selfish) equilibrium:
Blast your terminal! (ignore interf)

The two-device utility region



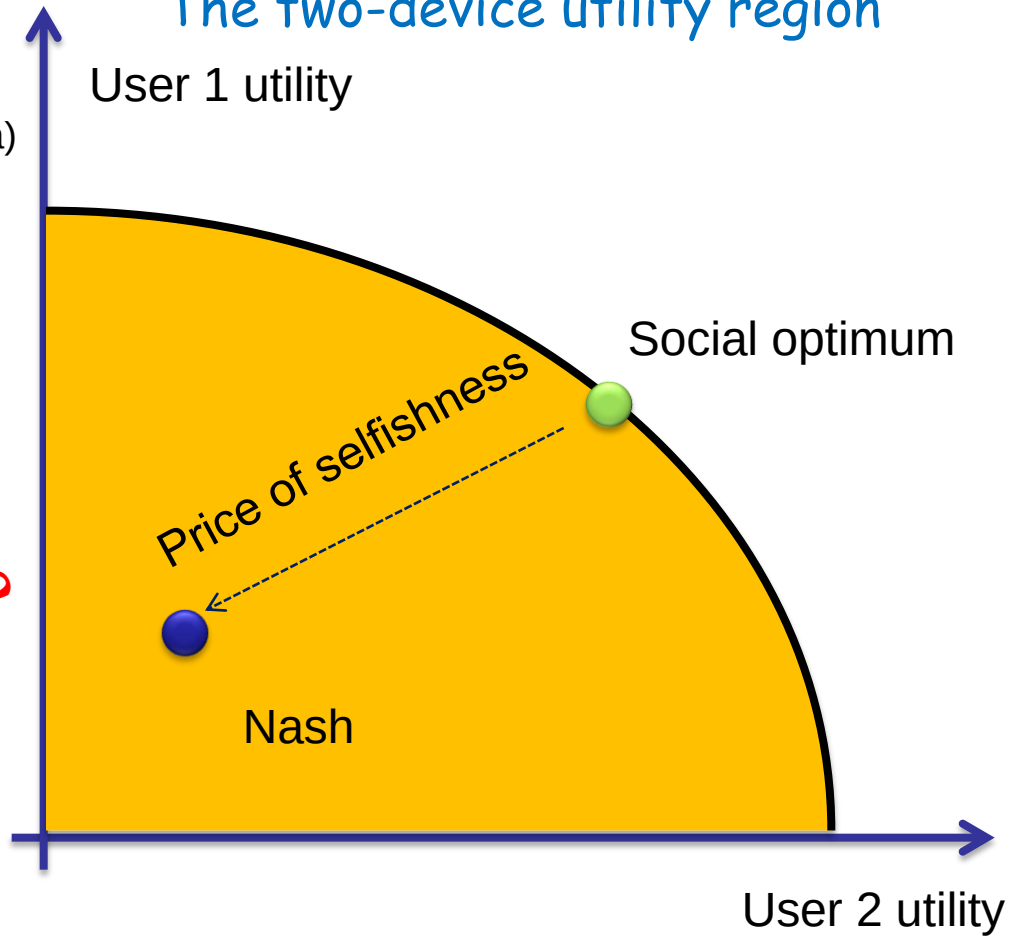
The price of selfishness

A two-device beamfoming game



Can you reduce price of selfishness while preserving autonomy of devices?

The two-device utility region



From wireless games to wireless teams

1. Wireless devices wish to cooperate towards maximizing a common utility
2. Each device has its own limited view over the system state (via local measurements)
3. Devices must come up with consistent strategies, which take into account the incompleteness/inaccuracy of one's and other's measurements

- Related to Bayesian game theory (Harsanyi, Nobel '94)

Team decision theory: Buying a baguette or not?

In 1936, a french couple returns separately from work and wants baguette for dinner. Personal cost for stopping at the baker is c_i .

Each person knows its own cost c_i. We assume that the c_i are uniformly distributed over [0,1].

Goal: maximize expectation of joint utility given by:

Person 2\Person 1	***Stop at Bakery***	***Go home***
Stop at Bakery	$a-c_1-c_2$	$1-c_1$
Go home	$1-c_2$	0

Who should stop for bread?

Team decision theory: Buying a baguette or not?

In 1936, a french couple returns separately from work and wants baguette for dinner. Personal cost for stopping at the baker is c_i .

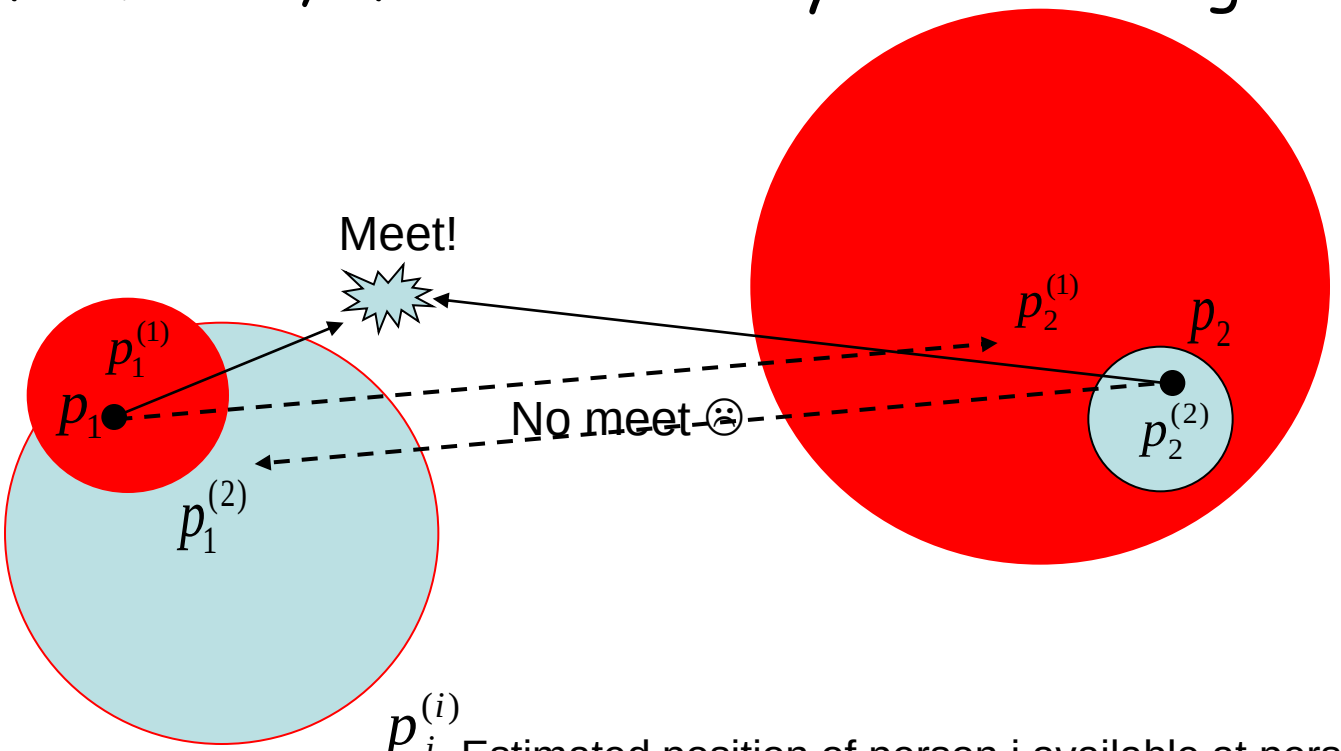
Each person knows its own cost c_i. We assume that the c_i are uniformly distributed over [0,1].

- *Optimal decision* $\gamma_i^*(c_i)$ *of threshold form*

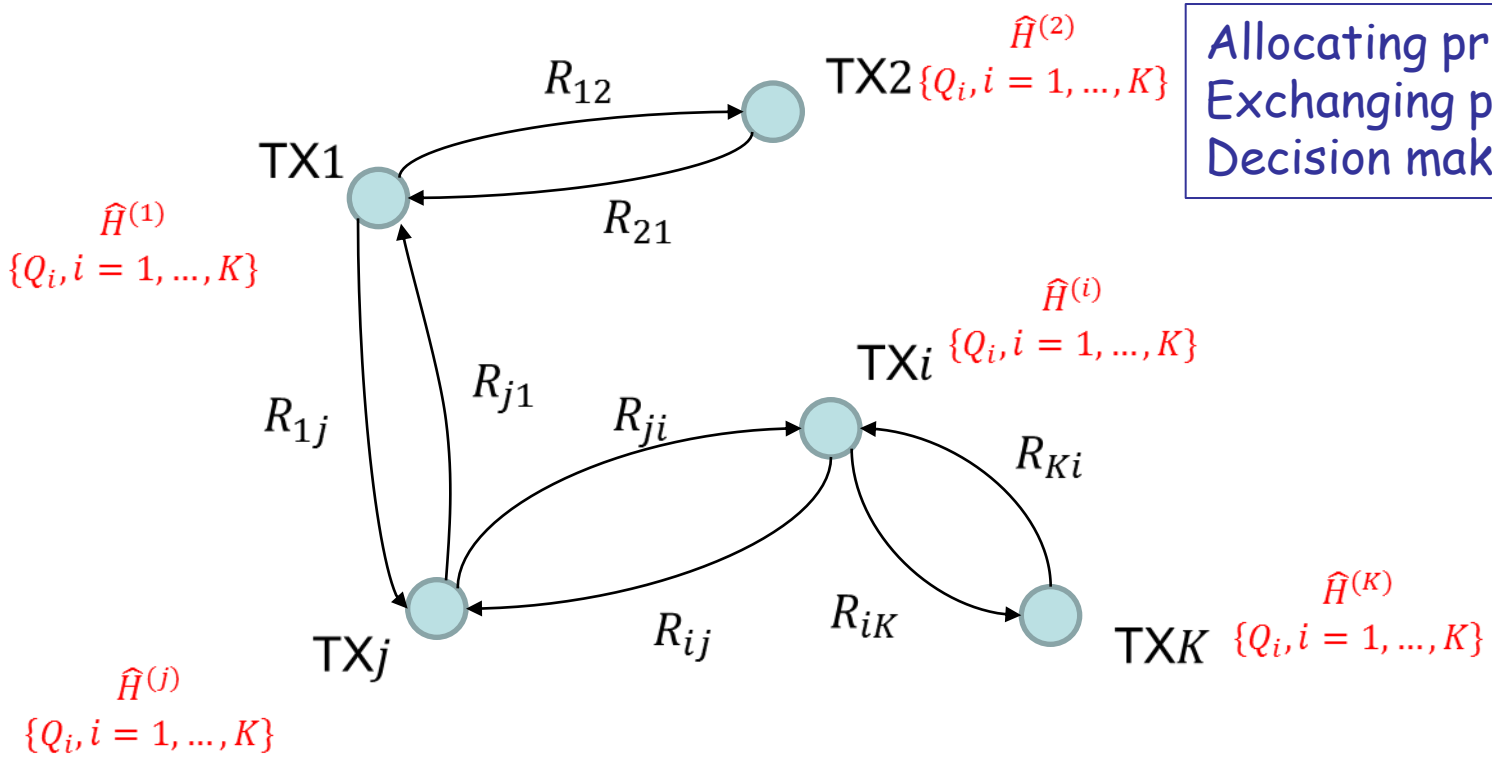
$$\gamma_i^*(c_i) = \begin{cases} \text{Buy bread if } c_i \le c_i^{th} \\ \text{Go home if } c_i > c_i^{th} \end{cases}$$

Team decision theory: The distributed Rendez-Vous problem

- Angel and his secret lover arrive in Chantilly separately seek to meet in minimum time
- They're allowed one short call to exchange (inaccurate) position information, after which they start walking…



Application to wireless: Coordination over a signaling graph



Allocating prior info?
Exchanging prior info?
Decision making?

A priori information:

$\widehat{H}^{(i)}$ Local state knowledge

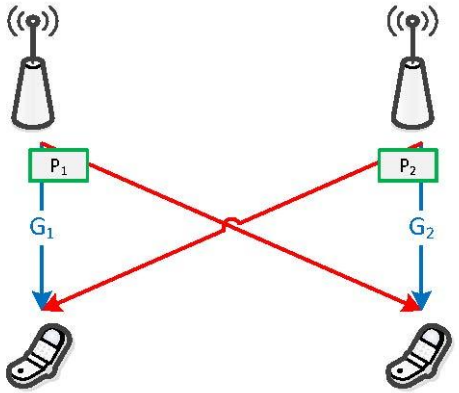
Q_i Information quality indicator

Coordination link rates:

From node i to node j: R_{ij}

Example 1: Team decisional power control

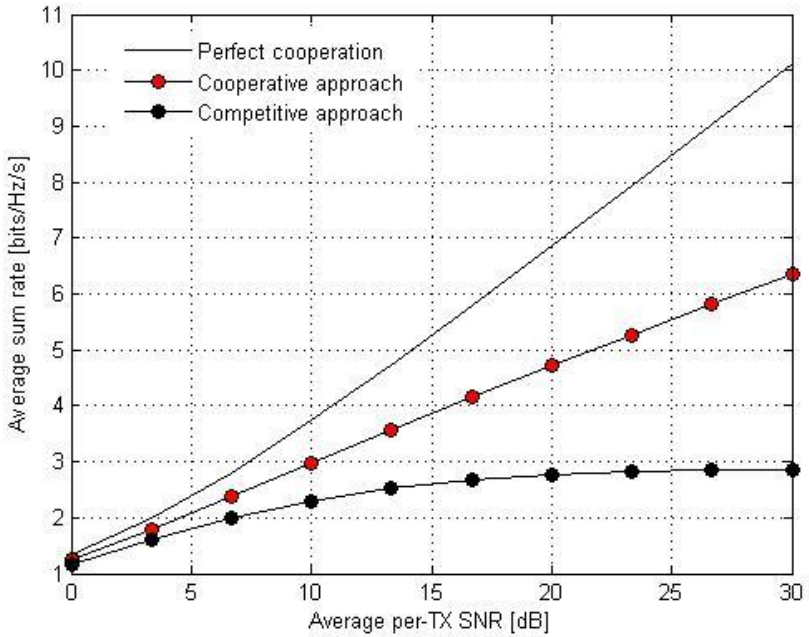
- Binary power control in wireless networks
  - *Direct links are known individually*
  - *Only statistics of the interfering links*
  - *Transmit with $P_i=P_i^{max}$, or remain silent $P_i=0$*
- Competitive approach:



$$P_i = P_i^{\max}$$

- Result: Team power control

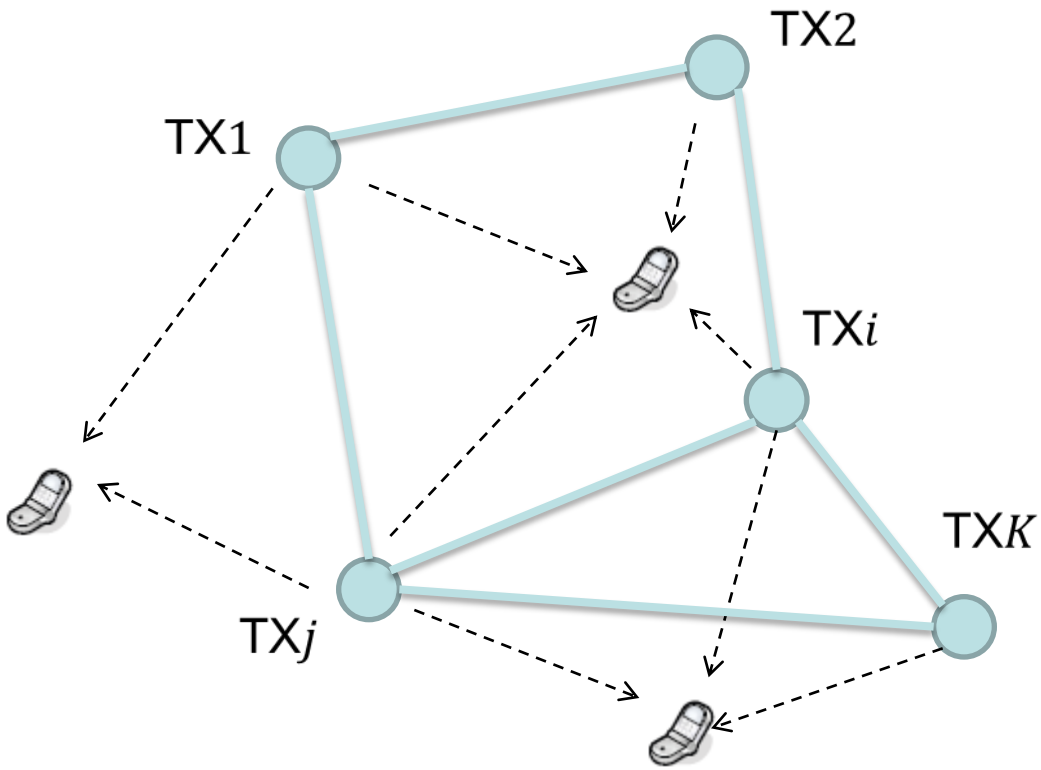
$$P_i = \begin{cases} 0 & \text{if } G_i < G_i^{th} \\ P_i^{\max} & \text{if } G_i \geq G_i^{th} \end{cases}$$

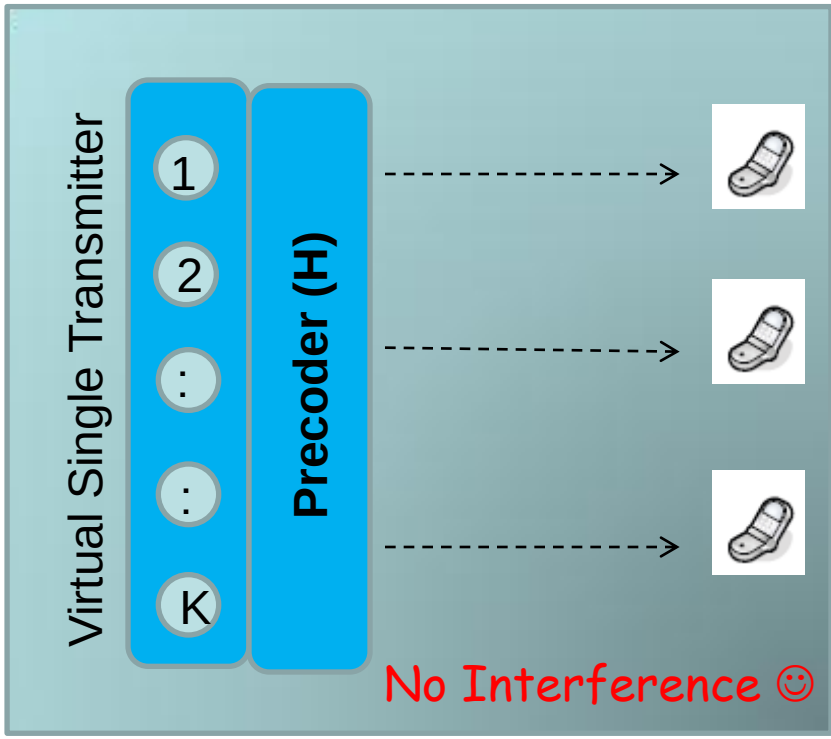


Example 2: Coordinated Precoding

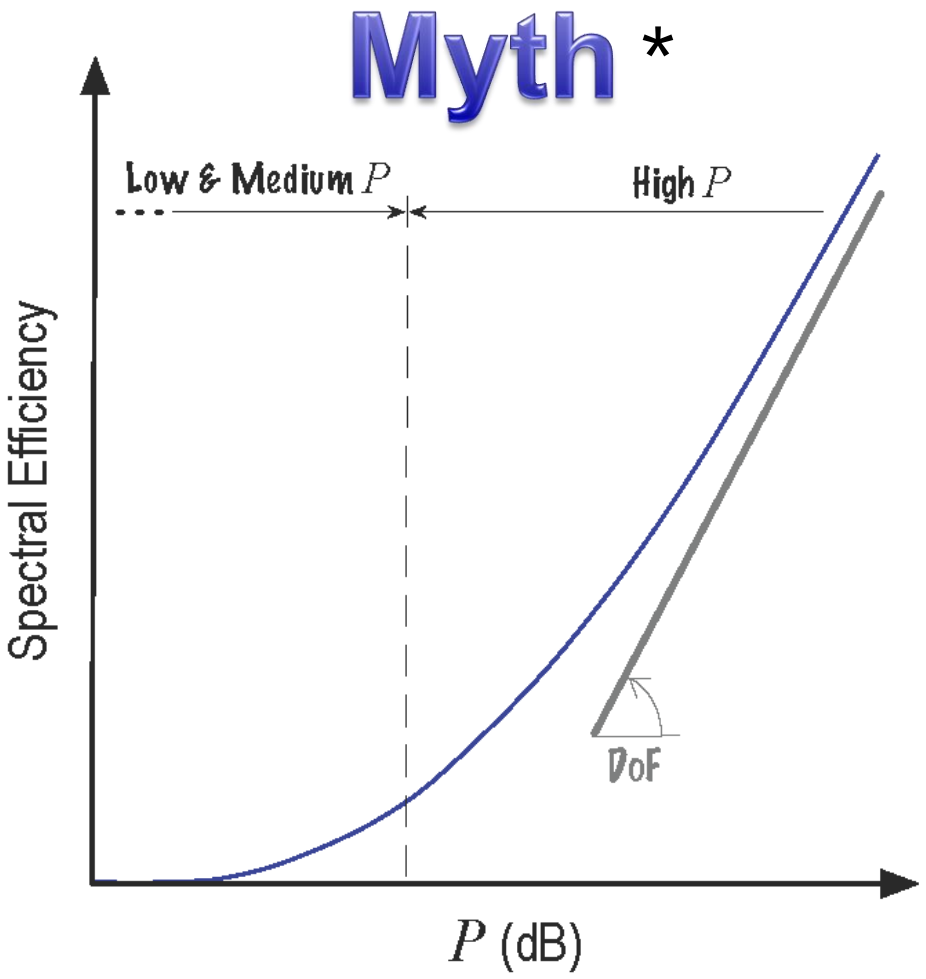
Discussed in LTE-A standard forum (CoMP)

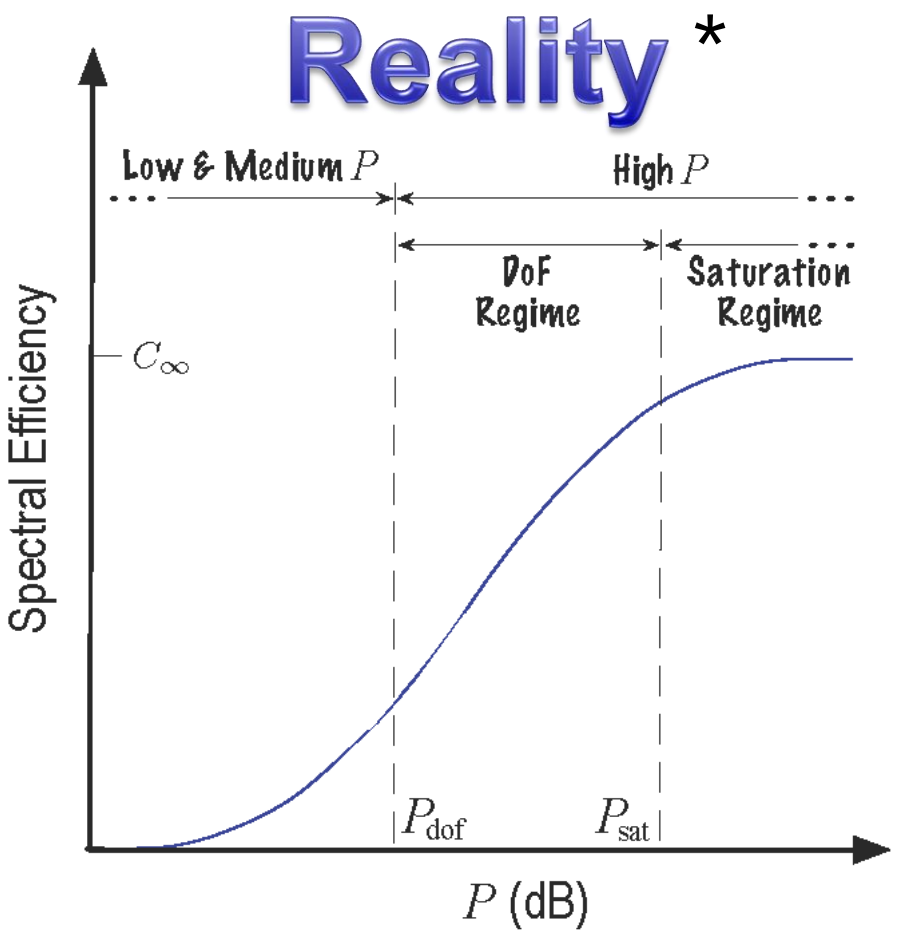
Basic assumption: $R_{ij} \gg 1, \hat{H}^{(i)} = \hat{H}^{(j)} \approx H$





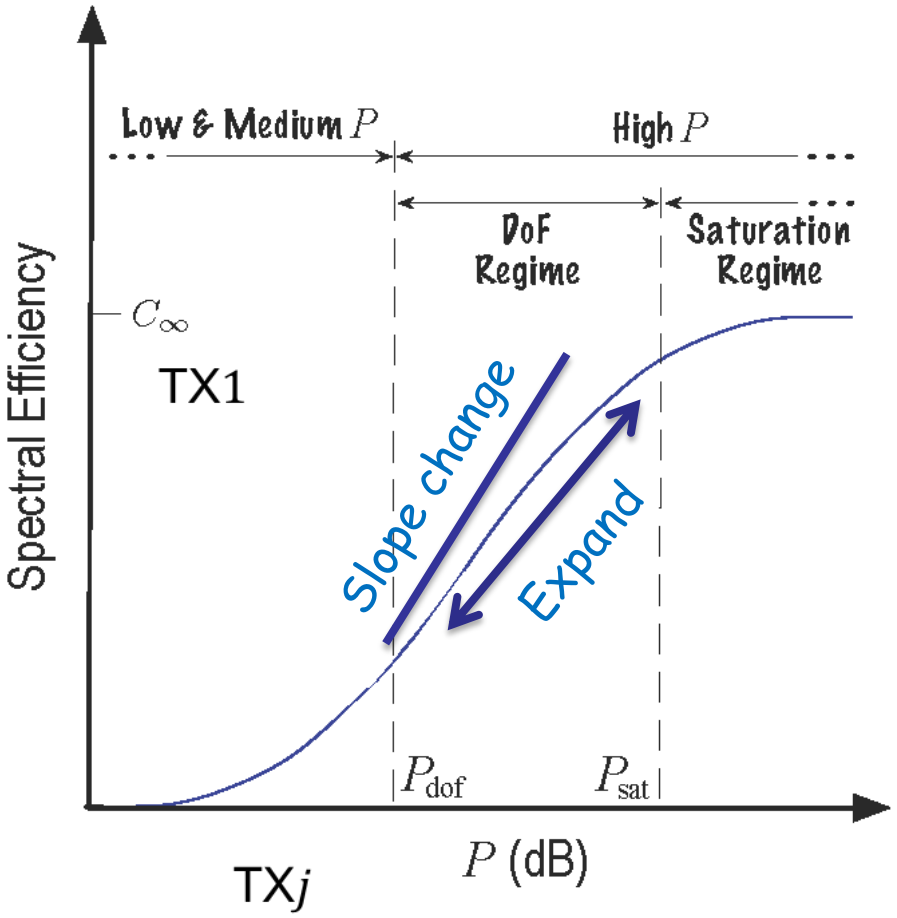
Transmitter cooperation: Myth and reality





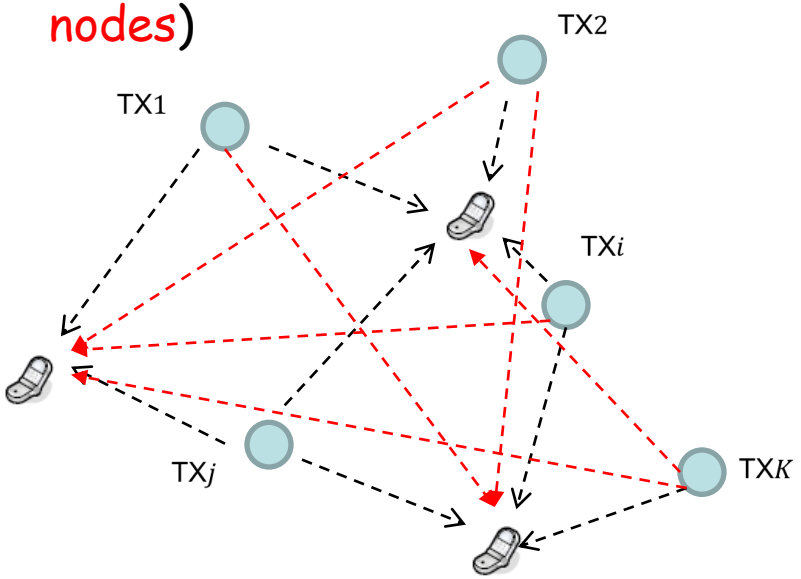
* *A. Lozano et al, "Fundamental limits of cooperation", IEEE Trans. On Information Theory, Sept. 2013.*

Transmitter precoding using team decision



Some lessons learned:

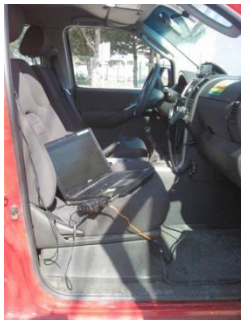
- Optimal spatial allocation of knowledge
  Scale knowledge according to interference strength
- Who knows more does more (Active-Passive coordination for two nodes)



Merci!

Open Source over-the-air radio experimentation

www.openairinterface.org



References available upon request at gesbert@eurecom.fr